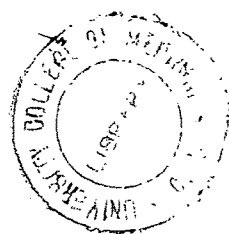


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JONATHAN L. BENUMOF, MD
CONSULTING EDITOR

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ANESTHESIOLOGY CLINICS OF NORTH AMERICA



Fiberoptics in Anesthesia

JAMES T. ROBERTS, MD, GUEST EDITOR



VOLUME 9 • NUMBER 1 • MARCH 1991

W. B. SAUNDERS COMPANY
Harcourt Brace Jovanovich, Inc.
PHILADELPHIA LONDON TORONTO MONTREAL SYDNEY TOKYO

W. B. SAUNDERS COMPANY
Harcourt Brace Jovanovich, Inc.

The Curtis Center
Independence Square West
Philadelphia, PA 19106-3399

P24629

The *Anesthesiology Clinics of North America* is also published in translated editions by the following:

- | | |
|------------|--|
| Italian | Verduci Editore, Via Gregorio VII 132, 00165 Rome, Italy |
| Portuguese | Interlivros Edicoes Ltda., Rua Comandante Coelho 1085, 21250 Cordovil, Rio de Janeiro, Brazil |
| Spanish | Nueva Editorial Interamericana, S. A. de C. V. Cedro 512, Apartado 26370, 06450 Mexico D. F., Mexico |

The *Anesthesiology Clinics of North America* is covered in *Current Contents/Clinical Medicine*, *Excerpta Medica*, and *ISI/BIOMED*.

ANESTHESIOLOGY CLINICS OF NORTH AMERICA
March 1991 Volume 9, Number 1

ISSN 0889-8537

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The *Anesthesiology Clinics of North America* (ISSN 0889-8537) is published quarterly by W. B. Saunders Company. Corporate and Editorial Offices: The Curtis Center, Independence Square West, Philadelphia, PA 19106-3399. Accounting and Circulation Offices: One East First Street, Duluth, MN 55802. Second class postage paid at Duluth, MN 55806, and additional mailing offices. Subscription price is \$74.00 per year (U.S. individuals), \$92.00 per year (U.S. institutions), and \$98.00 per year (foreign). There is a postage charge of \$8.00 for subscriptions shipped outside the United States. POSTMASTER: Send address changes to the *Anesthesiology Clinics of North America*, W. B. Saunders Company, Customer Service, P.O. Box 6467, Duluth, MN 55806-9854.

The editor of this publication is Maureen O'Gibney, W. B. Saunders Company, The Curtis Center, Independence Square West, Philadelphia, PA 19106-3399.

FIBEROPTICS IN ANESTHESIA

CONSULTING EDITOR

JONATHAN L. BENUMOF, MD, Professor of Anesthesiology, University of California
San Diego Medical Center, San Diego, California

GUEST EDITOR

JAMES T. ROBERTS, MD, Professor, Department of Anesthesia, Massachusetts
General Hospital, Boston, Massachusetts

CONTRIBUTORS

ELIZABETH C. BEHRINGER, MD, Instructor in Anesthesia, Department of
Anesthesia, Harvard Medical School; Director, Post Anesthesia Care Unit,
Massachusetts General Hospital, Boston, Massachusetts

STEPHEN F. DIERDORF, MD, Professor of Anesthesiology, Indiana University School
of Medicine, Indianapolis, Indiana

DON G. HAN, MD, Resident in Anesthesiology, The Mount Sinai School of Medicine,
New York, New York

ANDREW HERLICH, DMD, MD, Assistant Professor of Anesthesiology/Critical Care
Medicine, University of Pittsburgh School of Medicine; Staff Anesthesiologist, Eye
& Ear Hospital of Pittsburgh, Pittsburgh, Pennsylvania

WILLIAM E. HURFORD, MD, Assistant Professor of Anesthesia, Harvard Medical
School; Assistant Anesthetist, Massachusetts General Hospital, Boston,
Massachusetts

MARY KRAFT, MD, Instructor in Anesthesia, Harvard Medical School; Assistant
Anesthetist, Department of Anesthesia, Massachusetts General Hospital, Boston,
Massachusetts

NATAN NOVISKI, MD, Pediatric Pulmonologist, Hadassah University Hospital,
Jerusalem, Israel; Fellow, Pediatric Intensive Care Unit, Massachusetts General
Hospital, Boston, Massachusetts

ANDRANIK OVASSAPIAN, MD, Director, Department of Anesthesiology, V.A.
Lakeside Medical Center, Chicago, Illinois

VIJAYALAKSHMI U. PATIL, MD, Assistant Professor, Department of Anesthesiology,
SUNY Health Science Center, Syracuse, New York

ALLAN P. REED, MD, Assistant Professor of Anesthesiology, The Mount Sinai School
of Medicine, New York, New York

GEORGE D. SHORTEN, FFARCS(I), FCAnaes, Instructor in Anesthesia, Harvard
Medical School; and Clinical/Research Fellow, Massachusetts General Hospital,
Boston, Massachusetts

RICHARD M. SOMMER, MD, Assistant Professor of Anesthesiology, New York
University School of Medicine; Chief, Anesthesiology, Department of Veterans
Affairs Medical Center, New York, New York

I. DAVID TODRES, MD, Director, Neonatal and Pediatric Intensive Care Units,
Massachusetts General Hospital, Boston, Massachusetts

CHARLES B. WATSON, MD, Chairman, Department of Anesthesiology, Bridgeport
Hospital, Bridgeport, Connecticut

SHARON J. YELICH, MD, Assistant Professor, Clinical Anesthesia, Northwestern
University Medical School, Chicago, Illinois

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ERRATUM

In the September 1990 issue of the *Anesthesiology Clinics of North America*, Page 604, Table 1, the use of Erythropoietin as a perioperative alternative to blood transfusions for the Jehovah's Witness should have been listed in the Potentially Acceptable category.

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Vladimir Kvetan, MD and

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September 1991

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June 1990

POSTANESTHETIC CARE UNIT PROBLEMS

Gerald Shapiro, MD, MPA, *Guest Editor*

FOREWORD

The use of fiberoptic endoscopic equipment in anesthesia is now so important and essential to the administration of high quality anesthesia and intensive care that every anesthesiologist should have the equipment immediately available in his practice. There are multiple reasons why fiberoptic equipment improves anesthetic care. First, fiberoptic endoscopy-aided single lumen endotracheal tube intubation in the awake or generally anesthetized patient is now recognized as an indispensable tool in the management of the difficult airway. Second, fiberoptic bronchoscopy is considered by most authorities to be the best way to confirm proper position of double lumen tubes and bronchial blockers and endobronchial location of single lumen tubes. Third, fiberoptic bronchoscopy is an extremely important diagnostic tool, both in the operating room and intensive care unit for such conditions as obstructed airways (blood, secretions, masses) and airway burns. Fourth, a fiberoptic bronchoscope permits precise therapeutic lavage, suctioning and reinflation of any specific and/or all parts of the airways. Thus, an anesthesiologist may need to use a fiberoptic endoscopic piece of equipment, either emergently or electively, with single lumen tubes or double lumen tubes for diagnostic and/or therapeutic reasons.

Continuing education in Fiberoptics in Anesthesia is very important at this time. Since the widespread use of fiberoptics in anesthesia is a relatively new development (certainly, less than a decade) most anesthesiologists in practice today went through their residencies without any exposure to or use of fiberoptic equipment. Clearly, this large group of anesthesiologists will greatly benefit by a high quality educational effort in this area. However, the field is a rapidly changing one and continually embraces new advances and techniques so that even a newly graduated anesthesiologist will benefit from study on this subject. Finally, there is no good current single teaching text available on Fiberoptics in Anesthesia at the present time.

Dr. Roberts is extremely well qualified to guest edit this issue of *Anesthesiology Clinics of North America* on "Fiberoptics in Anesthesia." He has had a long-standing interest in the management of the difficult airway and since 1979 has been the Director of the Harvard Medical School Course on the Management of the Difficult Airway. He has authored chapters in both the surgical and anesthesia literature on this subject and, more importantly, has single-authored a book on this subject, *Fundamentals of Tracheal Intubation*, New York, Grune and Stratton, 1983. It is not surprising then, as fiberoptics were being introduced into clinical anesthesia, that he became a leading expert in this area. In fact the quality and quantity of his contributions in this area have been explosive. He has authored original articles, directed highly successful courses and workshops

on fiberoptic intubation at both the State and National (ASA) levels, produced numerous educational video tapes and exhibits, and has patented a laryngoscope specifically for teaching purposes. He knows the field well and anyone with any familiarity with the field will immediately recognize the stellar group of authors he has assembled to write about the field of Fiberoptics in Anesthesia. In summary, every anesthesiologist will greatly benefit by reading this issue of *Anesthesiology Clinics of North America* on Fiberoptics in Anesthesia because the issue is an excellent treatment of a new, rapidly changing, and now an essential aspect of good anesthesia and intensive care.

JONATHAN L. BENUMOF, M.D.
Consulting Editor

PREFACE

Historically, laryngoscopes for the purpose of endotracheal intubation have used rigid metal blades. By their nature, rigid steel blades force the patient's anatomy to conform, at least in part, to the shape of the blade. Changing the patient's anatomy is not always possible, which accounts for failures. A significant advance in laryngoscopy occurred with the invention of the flexible fiberoptic laryngoscope.

The flexible fiberoptic laryngoscope conforms to the patient's anatomy rather than forcing the anatomy to conform to it. This distinction is critical. It explains why an intubation with a flexible fiberscope is successful after attempts with a rigid laryngoscope have failed to provide a reasonable view of the laryngeal opening. Large numbers of anesthesiologists now recognize the potential value of the flexible fiberoptic laryngoscope in their practice. It is hoped that the following pages will facilitate the clinical use of these superb new instruments.

JAMES T. ROBERTS, M.D.

Guest Editor

Department of Anesthesiology
Massachusetts General Hospital
32 Fruit Street
Boston, Massachusetts 02114

History of Fiberoptics in Anesthesiology

*Richard M. Sommer, MD**

During the past 24 years, fiberoptic endoscopes have been used by anesthesiologists for tracheal intubation, diagnostic examination of the upper airway, positioning of endotracheal tubes, diagnostic examination of the trachea, carina, and bronchial tree, positioning of double lumen tubes and bronchial blockers, and for removing foreign material from the bronchial tree. The small caliber and flexible physical characteristics allow these fiberscopes to be maneuvered into position in circumstances in which rigid instruments and direct visualization techniques would not work.

This article traces the development and use of fiberoptic endoscopy by anesthesiologists, beginning with tracheal intubation as it was practiced before the modern era.

EARLY HISTORY OF LARYNGOSCOPY AND TRACHEAL INTUBATION

Techniques for viewing the vocal cords have been known and practiced since the first century A.D. In those days mirrored surfaces and indirect laryngoscopy to obtain a view of the upper airway were used.⁶³

In 1543 Andreas Vesalius was the first to describe the technique of tracheal intubation when he reported the artificial ventilation of an animal via a tube which was inserted in the windpipe. In 1705 Kite invented a device that was to be used in the resuscitation of drowning victims. It was a curved metal tube designed for tactile guided insertion into the trachea. In 1792 Curry described human endotracheal intubation, which was performed with tactile guidance technique.^{8, 66}

Blind intubation technique for drowning victims was described by Herholdt and Rafn in 1796. Their technique involved securing the airway

*Assistant Professor of Anesthesiology, New York University School of Medicine; Chief, Anesthesiology, Department of Veterans Affairs Medical Center, New York, New York

with an endotracheal tube and the subsequent provision of mouth-to-mouth resuscitation.

The 19th century saw the advent of nasotracheal intubation, which was described by Desault in 1814. The first tracheal intubation for the administration of inhalational anesthesia was performed by MacEwen in 1878. A rigid tube was manually passed through the mouth and into the trachea with positioning guided by tactile technique.⁶⁶

The technique of direct laryngoscopy had not yet been developed. However, indirect evaluation of the larynx was described by Garcia in 1855 and a dental mirror was used for this observation. Labordette (1866) invented the laryngoscopy speculum, which also permitted an indirect examination of the vocal cords. The advantage this had over the dental mirror technique was that it allowed the tongue to be pushed out of the way and gave a better view of the larynx.⁶⁶

The work of O'Dwyer in 1880 probably did the most to popularize tracheal intubation technique. In that year he reported on tracheal intubation for maintenance of airway patency in patients who were suffering from upper airway obstruction caused by diphtheria. Nevertheless, the endotracheal tube was still being introduced via tactile technique and not by a method that involved visualization of the larynx.⁸

The use of cuffs on endotracheal tubes began in 1893 when Eisenmenger reported this technique. Subsequently, in 1905 Kuhn developed and applied most of the principles of general anesthesia administered via endotracheal tube that are in use today. However, many others contributed to the refinement of the technique over the years.⁶⁶

Jackson in 1909 and 1913 developed the techniques of bronchoscopy and insertion of endotracheal tubes while observing the larynx under direct vision. Janeway, also in 1913, described a battery powered laryngoscope for the insertion of endotracheal tubes. The laryngoscope employed a curved blade and allowed direct visualization of the larynx. In the early 1940s Macintosh and Miller wrote papers reporting the development of curved and straight laryngoscope blades.⁸

These contributions to tracheal intubation with tubes made of metal, rubber, and plastic involved either no laryngoscopy or direct laryngoscopy. Although the technique of direct laryngoscopy has great utility in more than 90% of cases, there are circumstances when this approach cannot be used to visualize the larynx. This problem led to the development of two adjuncts to direct laryngoscopy which gave the anesthesiologist an opportunity to "see around corners" and did not require a straight line approach to the larynx.

In 1956 Siker invented and described the mirror laryngoscope which bears his name. The blade consists of three portions with a mirror on the middle portion. It was inserted into the mouth using standard technique but instead of viewing the larynx directly the view was taken from the mirror, which provided an inverted image to the operator.⁷⁹

Huffman reported his study of the application of prisms to curved laryngoscope blades. Like the Siker mirrored blade this was designed to give a view of the larynx while using a laryngoscope blade and yet without establishing a straight line approach. Although these advances were helpful

and provided the anesthesiologist with additional ways to perform laryngoscopy and intubation they did not work in all cases and they required the insertion of a laryngoscope blade into the oral cavity.³²

DEVELOPMENT OF FIBEROPTICS

The properties of glass are such that when glass rods are heated, melted, and stretched to form a long, fine, threadlike structure they lose most of the physical characteristics of glass. Specifically, these fibers become flexible while still retaining the ability to transmit light along their length. By the process of reflection off the wall of the glass fiber, light entering one end of the fiber will be transmitted to and exit the other end. Glass fibers 5–25 microns in diameter have the qualities of flexibility and light transmission. This was known in the late 1800s and put into practical use in the 1920s and 1930s. In 1930 the first flexible gastroscope using the fiberoptic technique was developed.

A single glass fiber is capable of transmitting light of uniform intensity and color. It is incapable of transmitting an image. For fiberoptic scopes to function, a large number of fibers must be arranged as a coherent bundle. Light at the objective end is focused on the bundle by a lens, the light is transmitted along the fibers, it exits the viewing end, it is focused by an eyepiece lens, and the observer views the image. The quality of the image is determined by the number of fibers in the bundle; a larger number of fibers results in a higher quality image.⁶³

In 1967 Murphy introduced the technique of fiberoptic scope guided tracheal intubation. The instrument that he used was originally designed as a choledochoscope which could slip down a 7.5-mm endotracheal tube without requiring lubrication. The technique which was employed was to pass the endotracheal tube as far as the nasopharynx. The endoscope was inserted until the tip of the endotracheal tube came into view at which point both the tube and scope were advanced together into the trachea. If the tube were directed to the side of the larynx the tube and scope would be redirected by rotating the endotracheal tube. The endoscope employed was short and its purpose was to provide an opportunity to merely visualize the direction the tube was taking, not to use the scope as a leader over which the tube would be passed.⁴⁹

The fiberoptic bronchoscope, an instrument of greater length than the choledochoscope, and one which incorporated a tip that could be flexed in two directions, was developed in Japan by the Machida Endoscope Company and Olympus Optical Company. In 1968 Ikeda reported the development and use of these instruments and thus the technique of flexible fiberoptic bronchoscopy began.³⁴ Conyers and colleagues⁹ reported their experience in a patient with rheumatoid arthritis. Since direct laryngoscopy had been unsuccessful in the past, airway control via elective tracheostomy prior to hip surgery had been planned. However, nasal fiberoptic scope guided intubation was performed with success, which obviated the need for tracheostomy. An Olympus BF-5B endoscope, a scope with a 5-mm diameter insertion cord, was passed through a 6.5-mm endotracheal tube.

Surface anesthesia was established with lidocaine to the nose and trachea and the fibroscope was introduced. The epiglottis and vocal cords were visualized, the insertion cord was passed into the trachea, and the endotracheal tube was advanced into final position.⁹

That same year Taylor and Towey also reported the use of fiberoptic guided intubation technique in awake patients with topical anesthesia.⁸⁸

Stiles and colleagues⁸⁴ published their experiences with a flexible fiberoptic laryngoscope. Unlike the previous reports, their scope had a short insertion cord of 45-cm working length (the bronchoscopes were 55–60 cm) but the tip of the scope was able to flex more than 180 degrees. The tip of their scope was less than 6 mm in diameter. Unlike the other papers published in that seminal year, they reported their experience with oral and nasal fiberoptic intubation in 100 patients. They had four failed intubations that were caused by copious secretions. They also reported that the endotracheal tube might be difficult to advance because it became caught on the laryngeal structures. However, by rotating the endotracheal tube in a spiral fashion over the scope it could be advanced freely. Finally, they pointed out the fact that the technique of fiberoptic intubation could be performed in less than 1 minute if the endoscopist had sufficient experience.

In 1973 Davis¹³ developed and described a fiberoptic laryngoscope which was battery powered, had an insertion cord of 55 cm, a flexible tip length of 5 cm, and angle deflection of the tip of 90 degrees anteriorly and posteriorly. It was designed for fiberoptic guided intubation but it was mentioned that endotracheal tube position above the carina could be checked with this device. A scope similar to this would later be marketed by the American Optical Corporation.

Raj and colleagues⁶⁴ reported their experience with the use of flexible fiberoptic laryngoscopes. Employing the American Optical Machida Company laryngoscope (49-cm length, 6.25-mm diameter, 120 degrees tip deflection) they performed 50 tracheal intubations. Their findings were that the technique could be quite successful provided patients were adequately sedated and topically anesthetized. However, the scope could only fit through tubes larger than 7.5 mm because of the large diameter of the insertion cord. In addition, theirs was the first report of the use of the fiberoptic endoscope to determine the proper placement of a double lumen endobronchial tube, a technique which became popular in the late 1980s.

In 1974 Schwartz and coworkers⁷³ reported the use of nasal fiberoptic tracheal intubation in topically anesthetized patients who had Ludwig's angina. At that time the problems of airway maintenance and direct laryngoscopy in these patients were well recognized and tracheostomy with the patient awake was the usual procedure. Their approach gave anesthesiologists a way to avoid tracheostomy and still provide adequate airway maintenance.

The employment of the fiberoptic scope in airway management of the patient with head and neck trauma was reported by Mulder, Wallace, and Woolhouse.⁴⁸ They used the Olympus bronchoscope BF-5B and prepared their patients with oral and nasal lidocaine 4% spray and tracheal lidocaine 1% spray with occasional use of superior laryngeal nerve blocks. With the

fiberscope acting as a guide they were able to intubate these traumatized patients under visual control. They also advocated that the scope be employed as a first line approach and not as a last ditch effort when all else had failed and the airway was covered with secretions or blood.

In 1976 Wang et al described the use of the fiberscope in patients who were difficult to intubate.⁹¹ This was followed by a report of their experience with awake fiberoptic tracheal intubation in patients with cervical spinal cord injury who were scheduled for anterior cervical spine fusion. The advantage of using the fiberoptic scope in this patient population was that it would not be necessary to move the head and neck into the sniffing position in order to visualize the vocal cords; this maneuver would be required if direct laryngoscopy were performed. They pointed out that movement of the head and neck could exacerbate the spinal cord injury, a complication that one would like to avoid. Instead, they maintained the patient in tongs traction and used sedation and topical anesthesia to make the patient comfortable. They successfully intubated their six patients and no complications developed. Another contribution from this report was the desirability of having an oral airway intubator to guide the fiberscope and endotracheal tube. Their preference was the Berman II intubating pharyngeal airway.⁹²

In 1978, Davies¹¹ reported on the use of the fiberoptic laryngoscope in the management of cut throat injuries. The scope was used as a guide across the throat laceration and it permitted tracheal intubation from nose or mouth. This left the surgeon with unimpeded access to the site of injury, a circumstance which would not exist if a surgical airway were present.

Messeter and Pettersson⁴⁵ published their work with the fiberoptic scope when it was employed to facilitate tracheal intubation in patients with advanced rheumatoid arthritis who were scheduled for surgery. These were cases in which it was expected that direct laryngoscopy would be very time consuming and where fiberoptic technique would reduce complications and result in faster and safer tracheal intubation. They were highly successful with this approach and the complication of upper airway edema, a problem caused by prolonged direct laryngoscopy, was markedly reduced. Based upon their experience they recommended that this technique be chosen when difficulties were anticipated in order to save time and avoid complications. Keenan et al³⁷ reported their experience with a similar patient population. They found the instrument to be valuable in dealing with the laryngeal and tracheal deviation associated with this disease. Their experience involved 710 fiberoptic intubations, which was the largest series ever reported for the use of the fiberscope.

In 1981 Ovassapian, Doka, and Romsa⁵⁴ reported their successful use of the fiberoptic scope in managing the airway of a patient with acromegaly. Traditional intubation techniques were thought to be unlikely to succeed because of hypertrophy of the soft tissues, macroglossia, and prognathism. They were able to identify the vocal cords and intubate the patient via awake nasal fiberoptic technique and avoid tracheostomy for airway control. During the fiberoscopy they did notice the hypertrophy of the soft tissues and that the vocal cords appeared to be at the end of a tunnel.

Based upon their experience in the management of the difficult airway

Edens and Sia¹⁷ recommended the fiberoptic bronchoscope to facilitate tracheal intubation in awake, spontaneously breathing patients. In addition, they reported the superiority of the bronchoscope with its 60-cm insertion cord over the fiberoptic laryngoscope which had a shorter (46-cm) insertion cord.

By 1981 many reports of the benefits of fiberoptic guided tracheal intubation for the management of the difficult airway had appeared. Despite this, most anesthesiologists were reluctant to use the technique because they had not received training with the fiberscope or they had attempted fiberoptic intubation but had been unsuccessful. Witton⁹⁷ recognized this problem and wrote a paper in which the technique of fiberoptic intubation was described in a step by step fashion. He discussed the equipment, patient preparation, the importance of opening the pharyngeal space by displacing the tongue anteriorly, manipulation of the scope, the anatomy to be viewed, and passage of the endotracheal tube. His major teaching points were 1) the fiberscope technique should be chosen initially in the course of intubation, 2) the head should be properly positioned, and 3) the right index finger might be needed to free the tracheal tube from the arytenoids when it is advanced.

Over the years the fiberoptic technique has been used for a variety of indications. Stella et al reported their extensive use of the fiberscope in oral and maxillofacial surgery.⁸² Daum and Jones successfully intubated a patient with Klippel-Feil syndrome.¹⁰ That same year a patient with adult epiglottitis with history of difficult airway was intubated via awake orotracheal fiberoptic technique.⁶⁰ Rashid and Warlthier⁶⁵ used the fiberscope for the airway management of a patient with infected laryngocele.

Outside of the operating room the fiberscope was also used for airway management. Delaney and Hessler¹⁴ reported their experience with fiberoptic intubation in a busy urban emergency room. They performed 60 intubations and found that, with 10 successful intubation cases for each endoscopist, they had developed facility with the fiberscope. Cases in which intubation failed were associated with bleeding, tumor, and agitation.

Ovassapian et al⁵⁶ used fiberoptic intubation in 129 operating room cases in which the patients were at increased risk for aspiration. There was one failed intubation with this approach. Despite the use of topical anesthesia to the vocal cords and trachea there were no episodes of gastric acid aspiration.

The fiberoptic technique has not been free from problems and over the years they have been reported. In 1984 Siegel et al⁷⁸ described complete endotracheal tube obstruction by the scope when the outer cover of the scope formed a donut-shaped intussusception. The effect was to cause complete endotracheal tube obstruction. The patient could not be ventilated so the endotracheal tube and scope were immediately removed and the patient reintubated. Passing the fiberscope through the Murphy eye can lead to intubation failure or inability to remove the scope.⁵³ Moorthy and Dierdorf⁶⁶ described intubation difficulties because the endotracheal was directed towards the esophagus and did not follow the course of the fiberscope into the trachea.

Foreign body aspiration during endoscopy through the special endoscopy port of an anesthesia mask has also been reported.⁹⁸

Several important pieces of equipment were designed to deal with problems associated with oral fiberoptic intubation. In 1981 Childres⁶ demonstrated the hand-held surgical tongue retractor. The tongue would be displaced anteriorly in order to open the pharynx while fiberoptic laryngoscopy was attempted. He had used this technique by himself over 200 times without assistance and found it to be very useful in providing exposure of the larynx. He compared this technique with that of pulling the tongue forward with lung forceps and found it to be superior in expanding the hypopharynx and avoiding trauma to the tongue.^{6, 41} Vredevoe⁹⁰ employed oral and nasal airways that had been slit along their sides or posteriorly as aids to oral and nasal fiberoptic intubation. The important point was that whatever device or technique was used it was critical that the pharyngeal space had to be open in order to facilitate fiberoptic intubation.

The use of airway intubators was also recommended by Palazzo and Soltice,⁶¹ Williams,⁹⁶ and Goldiner and Rooney.²⁵ These devices were useful in maintaining a clear path to the larynx without having the tongue obstruct the view. They also prevented biting on the endotracheal tube and/or fiberoscope.

While many authors were recommending the use of small caliber bronchoscopes as guides to intubation Shulman and Trollope⁷⁷ reported the use of a small gastroscope for this purpose. The limitations of the technique were that it could only accept a 9.5-mm endotracheal tube, but its advantages were its ability to suction copious quantities of blood and secretions and it had tip deflection in four directions.

Adapters to standard equipment and modifications of anesthesia masks were developed during the 1980s to permit positive pressure ventilation while a second anesthesiologist was endoscoping the patient. Mallios⁴³ and Patil et al⁶² modified masks to permit the insertion of a laryngoscope without causing a leak of ventilating gases. McAlpine and Williams⁴⁴ recommended the use of an airway intubator with a dual-purpose connector and an adhesive transparent dressing around the face. Okuda et al⁵¹ modified an intubating mask with rubber glove fingers to perfect a seal around the scope. Imai and Kemmotsu³⁵ reported an adapter which attaches to the Laerdal mask through which the fiberoscope could be passed. Each of these devices and techniques permitted positive pressure ventilation by one anesthesiologist while another was performing fiberoptic intubation and facilitated the administration of general anesthesia until the trachea was intubated.

In some cases in which the fiberoptic scope was required for tracheal intubation attempts to visualize the larynx were unsuccessful. Translaryngeal guidewires that were passed retrograde into the mouth could be used as leaders for the fiberoscope. Tobias⁸⁹ passed the guidewire into the mouth and slid it through the Murphy eye of the endotracheal tube. The tube could be advanced to a point above the larynx and the fiberoscope could then be advanced through the main lumen of the endotracheal tube and into the trachea. This method was modified by Lechman and associates.³⁴ Instead of passing the guidewire through an endotracheal tube it was passed through the working channel of the fiberoscope. This way the scope could

be guided into the trachea and the endotracheal tube advanced over it.³⁹ A similar use of this technique was reported by Gupta and colleagues.²⁸ These techniques were useful in cases in which blood, secretions or deformity made it difficult to visualize the larynx.

Stone⁸⁵ and Foster²⁴ reported that the fiberscope could be used as if it were a bright light wand when excessive blood or secretions impeded visualization of the laryngeal structures.

Boucek and coworkers⁵ published their experience with percutaneous high frequency jet ventilation as an aid during fiberoptic intubation. This technique permitted jet ventilation via translaryngeal catheter and intravenous general anesthesia while fiberoptic intubation was performed from nose or mouth.

Insufflation of oxygen via the working channel of the fiberscope was found to improve oxygenation and keeps secretions away from the tip. Rothenberg et al⁶⁹ found this to be useful when intubating apneic patients with the fiberoptic scope.

In 1983 Ovassapian and colleagues⁵⁸ published their experience with nasotracheal intubation and the incidence and causes of failure. They found that of 413 cases they had a failure rate of 1.2%. Three major causes of failure were identified: presence of posterior pharyngeal wall tumor, inability to thread the tube over the fiberscope, and failure to identify the vocal cords. However, their impressive success rate was a tribute to the value of this technique when it was performed by experienced anesthesiologists. Schwartz et al⁷² found that inability to advance the endotracheal tube over the fiberscope was frequently due to impingement on a vocal cord or arytenoid cartilage. Counterclockwise rotation 90 degrees frequently relieved this problem.

The effect of fiberoptic nasotracheal intubation on hemodynamics was studied by Ovassapian et al⁵⁷ and Sutherland and Williams.⁸⁶ Sutherland and Williams found no significant changes in heart rate or blood pressure throughout the procedure when topical lidocaine was applied to nose and trachea and sedation was provided with fentanyl and diazepam. In contrast, Ovassapian reported a slight increase in heart rate and blood pressure when the endotracheal tube was placed in the nose and inserted in the trachea. However, it is important to note the fact that these changes in hemodynamics were very small, which would make this technique useful even in cases in which hemodynamic stability was required.

Smith and coworkers^{80, 81} found that when fiberoptic intubation was performed under general anesthesia heart rate and blood pressure increased during and after intubation when compared with the initial vital signs. Finfer et al²¹ found a similar result. However, like the hemodynamic effects in sedated patients, although there were statistical differences demonstrated, the clinical significance of these findings was small.

FIBEROPTIC BRONCHOSCOPY

The fiberoptic bronchoscopy technique was introduced in 1968 by Ikeda.^{20, 34} Sackner et al⁷¹ in 1972 and Lindholm et al⁴⁰ in 1974 described

the applications of the flexible fiberoptic scope for bronchoscopy. Tahir⁸⁷ described the administration of general anesthesia through the endotracheal tube while fiberoptic bronchoscopy was performed. In 1974 Grossman and Jacobi²⁷ calculated the minimal optimal endotracheal tube size (8.5 mm) for bronchoscopy with the adult fiberscope. Feldman and Huber²⁰ reviewed the use of the bronchoscope in the intensive care unit in dealing with critically ill patients. They pointed out the advantages of flexible bronchoscopy: maintenance of the endotracheal tube in situ, ability to continue to deliver positive end expiratory pressure, and the use of a T-adaptor to continue to ventilate the patient during bronchoscopy.

The 5.2-mm diameter adult bronchoscope and endotracheal tubes 8.5 mm or larger were recommended.²⁰ This provided a sufficiently large tube to permit adequate viewing and suctioning and an endotracheal tube which would accommodate the fiberscope, while allowing ventilation to continue. The major reasons for performing bronchoscopy in the intensive care unit were tracheobronchial drainage, nasotracheal suctioning, prevention or treatment of atelectasis, and evaluation of hemoptysis. The removal of foreign bodies could be performed better with the rigid bronchoscope.

Techniques for maintaining oxygenation during bronchoscopy have been described by Shinnick et al.⁷⁵ They developed an endotracheal tube adaptor that could maintain a closed breathing system while the bronchoscope was inserted. Hussain et al³³ published results of insufflation of oxygen during bronchoscopy. They demonstrated a beneficial effect on arterial oxygenation and saturation as long as the oxygen was administered. This technique also has applicability during fiberoptic tracheal intubation and prevention of hypoxia during that procedure.

Bronchoscopy through an endotracheal tube is usually performed with manual or mechanical ventilatory support. MacIntyre and colleagues⁴² reported their use of a jet ventilation endotracheal tube during bronchoscopy. The advantages of this technique over volume-cycled ventilation were that adequate ventilation could be maintained at lower airway pressures and with less air trapping.

A recent development has been the use of the bronchoscope in trauma patients to evaluate the upper and lower airway. Hara et al were able to diagnose tracheal, bronchial, and supraglottic injuries and lesions with this device.³⁰

FIBEROPTIC ENDOSCOPY IN PEDIATRIC INTENSIVE CARE UNITS

Rock and Klain⁶⁷ in 1976 described the use of the 3.5-mm fiberscope in pediatric intensive care. They found that it was valuable for determining the position of endotracheal tubes, evaluating the tracheal mucosa, and confirming or eliminating the possibility that the tube was obstructed. The advantage of this technique over other techniques is that it could be done at the bedside without moving critically ill children to other locations.

A vast experience with the flexible fiberscope in the pediatric intensive care unit was reported by Fan, Sparks, and Fix. The fiberscopes which

they used had outer diameters of the insertion cord of 1.8 mm, 2.7 mm, 3.7 mm, and 4.9 mm. The 1.8-mm and 2.7-mm scopes did not have a working channel and the 1.8-mm scope did not have a directable tip. The smallest scope was able to pass through a 2.5-mm endotracheal tube which provided utility even in some of the smallest patients. In their intensive care unit they performed laryngoscopy for the following indications: stridor, obstructive sleep apnea, hoarseness, respiratory distress, upper airway trauma, and evaluation of nasopharyngeal mass and epiglottitis. Bronchoscopy was used diagnostically for wheezing, stridor, tube patency and position, smoke inhalation, evaluation after extubation, and evaluation of lung mass, tracheal bleeding, and respiratory distress. The bronchoscope was used therapeutically to assist in the difficult intubation and remove secretions.¹⁹

The advantages of the flexible scope over rigid bronchoscopy are: it is a bedside procedure and does not require transfer of critically ill patients to the operating room; general anesthesia is not required; it can be performed on tracheally intubated patients; and it can aid in the placement of endotracheal tubes. The disadvantages are the child must breathe around the fiberscope; the use of sedatives has risks which may be as great as general anesthesia; and the examination may be difficult in uncooperative patients.

Etches and Finer¹⁸ reported that a 1.3-mm diameter fiberoptic catheter could be used to evaluate endotracheal tube patency and placement. The chief concern with the use of these devices was the increased ventilatory resistance they created. Nevertheless, these small catheters are valuable in the management of the intubated neonate.

ENDOTRACHEAL TUBE POSITION

The proper positioning of an endotracheal tube can be determined by use of the fiberoptic bronchoscope. Whitehouse and Klock used the American Optical fiberoptic laryngoscope and they were able to directly visualize the position of the endotracheal tube above the carina and the distance from tip of tube to the carina.⁹⁵ Moyers and Gregory⁴⁷ in that same year repositioned an endotracheal tube with fiberoptic scope guidance intraoperatively. This approach is advantageous because it reduces the risk of accidental extubation when it is anticipated that tracheal intubation will be difficult.

O'Brien et al demonstrated in adults that the fiberscope was as good as the chest radiograph in determining endotracheal tube position.⁵⁰ Dietrich and colleagues¹⁵ reported the same results in 24 critically ill pediatric patients. The advantage of this technique when compared with radiography is the time for confirmation of tube position can be substantially shortened and definitive positioning can also be determined with the fiberscope.

PEDIATRIC FIBEROPTIC INTUBATION

Fiberoptic tracheal intubation in infants and young children poses a special problem for anesthesiologists because of the small caliber of the

endotracheal tubes. The tubes can either be inserted over very small fiberscopes or modified fiberoptic techniques can be employed.

In 1974 Stiles⁸³ used the fiberoptic scope to intubate small children. The problem posed was to use an adult scope in children in cases in which it would not be possible to place an endotracheal tube over the fiberscope. The solution to this problem was to visualize the vocal cords with the fiberscope and advance a flexible cardiac catheterization guide wire through the working channel and into the trachea. The guidewire was stiffened by passing a cardiac catheter over it and the endotracheal tube was passed over the catheter/guidewire combination.

In 1979 Alfery and colleagues¹ intubated a neonate with congenital fusion of the jaws. They passed a 3.2-mm diameter fiberscope through the left nostril and obtained a view of the larynx. A 3-mm endotracheal tube was inserted through the right nostril and advanced into the trachea while the head and neck were manipulated.

Rucker and his group⁷⁰ used 5.8-mm and 3.2-mm endoscopes in the traditional manner to achieve fiberoptic-guided tracheal intubation. Of course, the limitation of this method is that tubes with inner diameters less than 4.0 mm or 3.5 mm may not slide over the 3.2-mm fiberscope.

Ford²³ adapted a standard fiberoptic laryngoscope for pediatric purposes. He taped an 8-inch red rubber catheter to the laryngoscope and inserted them into either the nose or mouth. With the larynx in view a cardiac catheter guidewire was passed through the rubber catheter and into the trachea. While maintaining the catheter in the trachea the fiberscope with rubber catheter were removed. Finally an endotracheal tube was passed over the cardiac catheter guidewire and tracheal intubation was accomplished. In pediatrics the limitation of this technique is the size of the nasal passages and whether they will permit the placement of the insertion cord with red rubber catheter attached.

Hemmer et al³¹ described the use of the pediatric (3.4-mm) fiberscope for the intubation of a child with cervical spine injury. In this case the scope was used as in adult cases with the endotracheal tube (4.5 mm) threaded directly over the scope. Baines et al³ used the fiberscope in the same way to intubate a 6-year-old child with a 5-mm endotracheal tube.

In 1987 Kleeman et al³⁸ used an ultrathin, 2.7-mm diameter fiberscope as a guide for tracheal intubation in three cases. Their technique involved visualization of the larynx with a 3.5-mm fiberscope and application of topical anesthetic via its working channel. Once that was accomplished the 3.5-mm scope was removed and tracheal intubation was performed over a 2.7-mm ultrathin scope.

Gouverneur and coworkers²⁶ managed a difficult pediatric airway by passing a ureteral catheter through the nose and into the trachea and sliding an endotracheal tube over it. The ureteral catheter was placed in the trachea while fiberoptic laryngoscopy was performed through the contralateral nasal passage.

In summary, over a 16-year period a variety of techniques have been developed to intubate the small trachea of pediatric patients. The techniques have involved the use of very small, thin scopes and/or the passage of thin leaders and guides into the trachea over which the endotracheal tube was passed.

DOUBLE LUMEN TUBE POSITION

The problem with double lumen tubes is making certain that the bronchial portion is inserted to the proper depth in the designated mainstem bronchus. Raj et al were the first to report the use of the fibroscope as an aid to the placement of double lumen endotracheal tubes.⁶⁴ Subsequently Shinnick and Freedman also reported the value of the fibroscope in double lumen tube positioning.⁷⁴

Aps and Towey² found the fibroscope to be valuable and a safe, easily learned technique for the proper positioning of single lumen endobronchial tubes. Ovassapian reported his experience with the fibroscope as an aid to positioning the double lumen tube and suggested that left tubes should be inserted such that the cuff was 1 cm distal to the carina and the opening of the tracheal lumen was 4 cm proximal to the carina.⁵²

Benumof et al⁴ studied the margin of safety in positioning double lumen endobronchial tubes and found that on the left the average safety margin was 16–19 mm and the right was 8 mm. He concluded from this that the left tube should be used whenever possible and that positioning should be confirmed with the bronchoscope.

Shulman et al⁷⁶ echoed the recommendation of using the fibroscope and suggested that the double lumen tube could be shortened at the proximal end in order to facilitate bronchoscopy if necessary.

CHANGING ENDOTRACHEAL TUBES

Rosenbaum and coworkers⁶⁸ reported the technique of changing an endotracheal tube with a fiberoptic scope. Their approach was to pass the tube into the trachea alongside a tube which was already properly positioned. The old tube would be removed and the new one passed over the scope and into the trachea. That same year their technique was endorsed by Watson⁹⁴ when he reported his experience with 15 endotracheal tube changes. In 1985 Halebian and Shires²⁹ reported the same technique for endotracheal tube changes. They were successful 27 of 29 times.

LEARNING FIBEROPTIC INTUBATION

Despite the fact that the fiberoptic scope has been demonstrated to be a valuable adjunct to airway management in anesthesiology its acceptance by many has been hindered by the fact that it requires the mastery of new skills. In order to overcome the reluctance of practicing clinicians and residents to attempt a new technique which was associated with potential failure a graduated program of training was developed by Ovassapian et al.^{55, 59} The training program employed models very successfully. Subsequently a controlled study was performed comparing the graduated program with a single demonstration of nasotracheal intubation on sedated patients. This study conclusively proved that the graduated program which involved

models and simulators resulted in 90% success versus 67% success with the "see one, do one" method.

Wangler and Weaver⁹³ suggested that the technique of fiberoptic intubation could be learned on normal patients by having the patient spontaneously breathe volatile anesthetic through a nasopharyngeal airway. While that took place fiberoptic intubation could be performed through the other nostril. This provided patient comfort via the anesthetic and time for trainees to visualize the anatomical structures on patients.

Davies and Hollway¹² also used inhalation technique and spontaneous ventilation for learning fiberoptic technique and they emphasized the importance of having one anesthesiologist manage the airway while the other performed the endoscopy.

Coe et al⁷ devised an approach similar to that of Wangler and Weaver except they employed an oral airway which was attached to the breathing system instead of the nasal airway technique. Nasal fiberoptic intubation was performed for tracheal intubation while the patient was spontaneously breathing halothane and oxygen.

Dykes and Ovassapian¹⁶ found that 35% of attendees at a workshop on fiberoptic intubation were subsequently able to use the technique in their practice. This suggested that a new psychomotor skill could be learned by clinicians after they had received lectures and written materials and after they had perfected their skills with inanimate models.

Johnson and Roberts³⁶ found that residents could be trained to perform fiberoptic intubation in less than 2 minutes on a consistent basis if they had 10 previous successful experiences. Patients were given intravenous general anesthesia and ventilated with oxygen and enflurane. They remained apneic during fiberoptic laryngoscopy and they were intubated orally.

Forbes and coworkers²² found that the pig provided an excellent live model for developing fiberoptic skills. Pigs were anesthetized with inhalation agent and oral and nasal fiberoscopy were practiced. Participants found this technique to be superior to using the intubating manikin for practice.

In summary, a variety of techniques, including practice with manikins and animals, and experience intubating patients, have been found to be useful in acquiring the skills of fiberoptic intubation.

CONCLUSION

Fiberscopes were introduced into anesthesiology in 1967. Since then they have been used extensively for diagnostic and therapeutic purposes. Over the last 20 years there has been an explosion of information with regard to indications for fiberoscopy, devices for facilitating the use of the scope, and methods for learning the psychomotor skills of fiberoptic intubation.

Anesthesiologists have found the fiberoptic bronchoscope to be superior to the fiberoptic laryngoscope because of its longer length and ease of use. Manufacturers have designed, manufactured, and marketed thinner scopes which have been used for adult and pediatric fiberoscopy.

Interestingly, none of this could have occurred were it not for the fact

that the physical properties of glass are such that it transmits light and it becomes flexible when it is stretched into long thin strands.

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Address reprint requests to

Richard M. Sommer, MD
Department of Anesthesiology
New York University Medical Center
550 First Avenue
New York, NY 10016

Types and Physics of Fiberscopes

*Stephen F. Dierdorf, MD**

In 1854, John Tyndall demonstrated that light could travel in a curved line, but it was not until the 1950s that this discovery was used for medical purposes. Hopkins and Kapany⁴ reported the development of a flexible fiberoptic unit that could convey images. Prior to the development of fiberoptics, endoscopes used a series of lenses, which resulted in a poor-quality image. Poor illumination permitted very little magnification; endoscopy was tedious and required a certain amount of good fortune to locate and examine a suspected lesion. Soon after the report by Hopkins and Kapany the first fiberoptic endoscope was introduced,³ and fiberoptic technology provided high-quality images. The first fiberoptic endoscope was a gastroscope and was introduced by Hirschowitz in 1957, but it was not enthusiastically received by medical practitioners. The first report of a successful flexible fiberoptic tracheal intubation was in 1967 when a choledoscope was used as the endoscope for a nasotracheal intubation.⁷ In 1972, a bronchoscope was first used for awake tracheal intubations.¹⁰ Since that time there have been dramatic improvements in the design and production of fiberoptic endoscopes. Several manufacturers now produce high-quality flexible fiberoptic laryngoscopes for anesthesiologists' use. Fiberoptic technology has wide application not only for flexible bronchoscopy but has been incorporated into rigid bronchoscopes and traditional laryngoscopes as well.

This article explains the physical principles essential to fiberoptic transmission. Familiarity with the physical principles of fiberoptic light and image transmission along with knowledge of how a fiberscope is constructed provides a better understanding of the capabilities and limitations of fiberoptic endoscopes. This will make learning techniques of fiberoptic laryngoscopy and tracheal intubation easier and will minimize the risk of damage to the equipment. Fiberoptic airway endoscopy has become an integral part of anesthesiology practice and anesthesiologists must be skilled in the use of fiberoptic equipment.

*Professor of Anesthesiology, Indiana University School of Medicine, Indianapolis, Indiana

PHYSICS OF FIBEROPTIC IMAGE TRANSMISSION

The physical principle that governs image transmission via flexible fiberoptic bundles is the law of total internal reflection, meaning that light can be totally reflected internally by the fiberoptic strand. Relative to the transmission medium, light rays can be termed as meridional or skew. Meridional rays pass through the axis of the conducting fiber without being reflected. Skew rays do not intersect the fiber axis and can be internally reflected.¹¹ Normally, as a ray of light traverses the boundary between two media (e.g., air and glass) the light ray will be split into two parts; most of the light will pass into the air and be refracted, but part of the light will be reflected back into the glass (Fig. 1). Light refraction occurs because the speed of light through material is lower than the speed of light through air. The higher the refractive index of a material, the slower the speed of light in that material. The degree of reflection will depend on the angle of incidence of the light and the refractive indices of the two transmission media. As the angle of incidence increases, a point is reached where the refracted light travels parallel to the boundary surface. The angle at which parallel transmission occurs is termed the "critical angle" (Fig. 2). If the incident angle is, however, increased beyond the critical angle then total internal reflection of the light will be achieved (see Fig. 2). A simple example of total internal reflection is the prism system in a pair of binoculars. Binoculars, however, require only four reflections, whereas a fiberoptic bundle requires numerous reflections. Total internal light reflection is the underlying physical principle that permits light transmission through flexible glass fibers. A waveguide is constructed when a transparent material is layered between a material with a lower index of refraction.¹² Within the waveguide it is then possible for a light ray to be reflected numerous times and zigzag along the entire course of the fiber (Fig. 3). Early practical attempts at total internal light reflection were frustrated because damage or debris contamination of the boundary surface allowed light to leak through the fiber walls, resulting in a poor-quality image. This problem was overcome by coating (cladding) the surface of the fiber with a material with a lower index of refraction. A fiber consists of two parts: the core or light transmission part and the cladding material (Fig. 4). The internal boundary surface between the core and the cladding, which is then

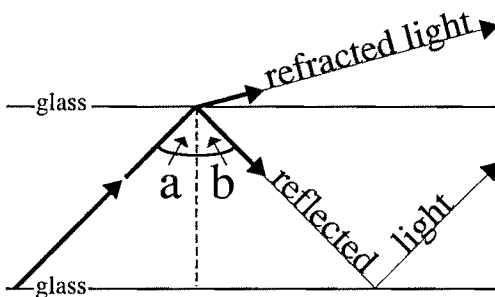
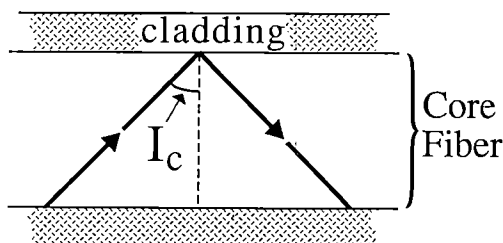


Figure 1. As light meets a glass-air interface, most is refracted but some is reflected. Angle a is the angle of incidence and angle b is the angle of reflection.

Figure 2. Light striking the boundary of a clad glass fiber will be internally reflected. I_c is the critical angle. Light striking the boundary at an angle greater than the critical angle will undergo total internal reflection.



protected from damage, becomes the reflection surface. It is the cladding of the glass bundle that allows the wide medical application of flexible fiberoptics. Current materials and technology permit total internal reflection with only 0.001% light loss per reflection. There is, however, a limit to the amount of light that will be accepted by the fibers for transmission. Light entering the bundle at an angle lower than the critical angle for the interface will not be reflected. Other factors that decrease the amount of light accepted by the fiber include light scatter at the interface, light absorption by the core glass, and packing fraction loss. The packing fraction is the ratio between the cross-sectional area of the cladding material and the cross-sectional area of the core material. For endoscopes, fibers are arranged in bundles. The core or light-transmission fibers are each surrounded by the cladding material. The cladding material does not transmit light and any light striking the cladding material is lost. In order to improve image resolution a large number of small fibers is desirable; however, fiber density is limited because the packing fraction loss increases as fiber density increases.

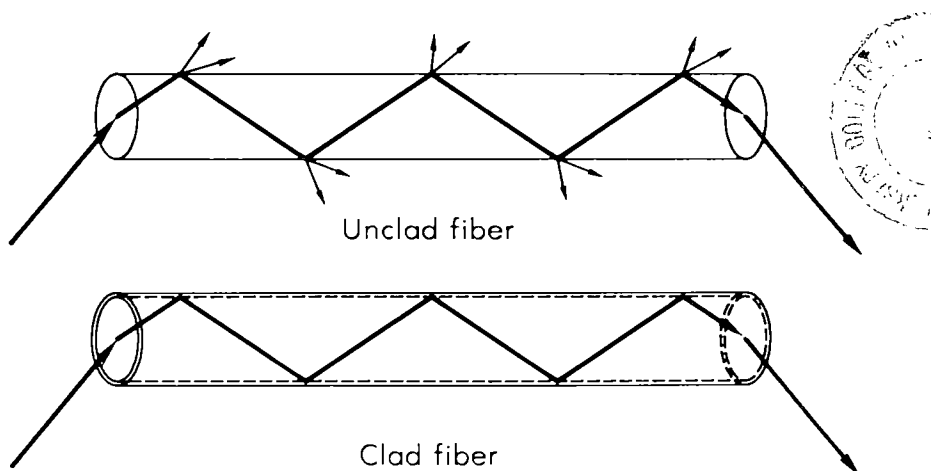


Figure 3. An unclad fiber with a contaminated surface loses light throughout its length. Cladding protects the interface surface and increases transmission efficiency. (From Tams T (ed): Small Animal Endoscopy. St Louis, The C.V. Mosby Company, 1990, p 5; with permission.)

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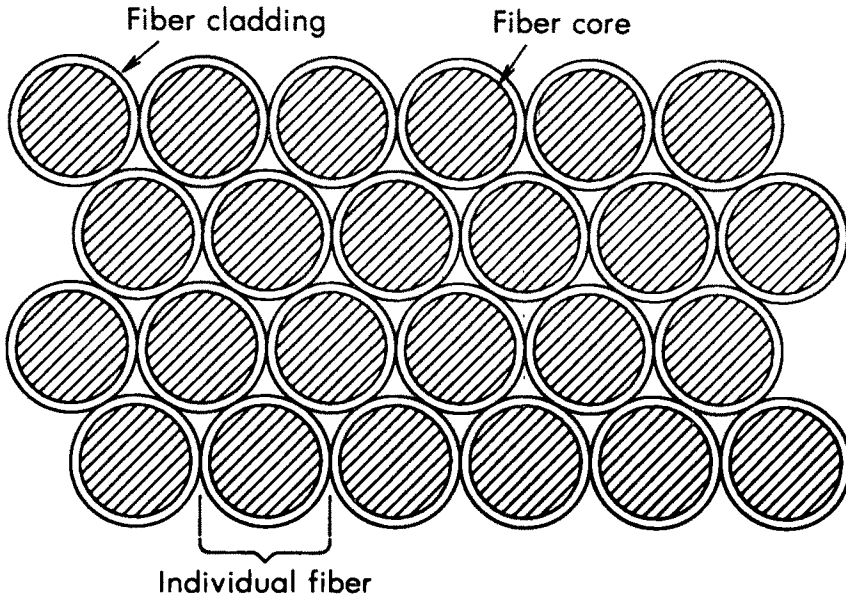


Figure 4. Individual fibers are grouped into a bundle in a honeycomb pattern. Only the light falling on the core glass (*shaded area*) is transmitted. (From Tams T (ed): *Small Animal Endoscopy*. St Louis, The C.V. Mosby Company, 1990, p 7; with permission.)

The other essential practical factor important to the development of fiberoptic light transmission was the use of glass of high purity and transparency because glass with impurities is unsuitable for light transmission. For all practical purposes, current manufacturing produces silica-based glass that is at the theoretical limit of its transparency. Consequently, materials with higher degrees of transparency are being developed. These newer materials are important for the transmission of laser energy. Infrared fiberoptic light transmission is of special interest to the communication industry. Fiberoptic signals transmitted by silica-glass fibers must be reamplified every 10 to 50 kilometers. Infrared signals, however, only require reamplification every hundreds or thousands of kilometers.² Infrared signal transmission does require fibers of a material different than silica glass. Current research interest has been focused on production of metal fluoride glass fibers.

FIBERSCOPE COMPONENTS

There are three basic parts of a fiberoptic endoscope: the body; the insertion cord; and the light-transmission cord (Table 1; Fig. 5).⁸ The components of the insertion cord are of special importance because it is these components that give the instrument flexibility while transmitting a high-quality image. The components of the insertion cord can be subdivided into the fiberoptic bundles, the optical system, and the mechanical system.

Table 1. *Components of a Flexible Fiberoptic Laryngoscope*

Body	Insertion cord
tip deflection control lever	working channel
eyepiece	image transmission bundle
focusing ring	light transmission bundle
working channel sleeve	Light transmission cord

Fibers and Bundles

A single glass fiber can transmit light but not an image. Image transmission requires a large number of bundles arranged in a coherent bundle.¹ A coherent bundle is constructed by precisely arranging the individual fibers so that fibers at one end of the bundle are perfectly arranged in the same relative location at the other end of the bundle. Incoherent bundles have fibers arranged in random order and can transmit light but not an image (Fig. 6). Incoherent bundles are easier and less expensive to construct and are generally used as light conduits, referred to as light guide (LG) bundles, in endoscopes. The resolution power of the endoscope is determined by the density of the fibers in the bundle; the higher the density, the better the resolution. The diameter of the basic fiber elements of most imaging fiberscopes is 8 to 10 microns. The cladding material surrounding each fiber is 0.5 microns thick. Bundles used for fiberoptic laryngoscopy contain 4000 to 6000 of these individual fibers. Fiberoptic fibers can be made from glass or plastic. Because of the light-

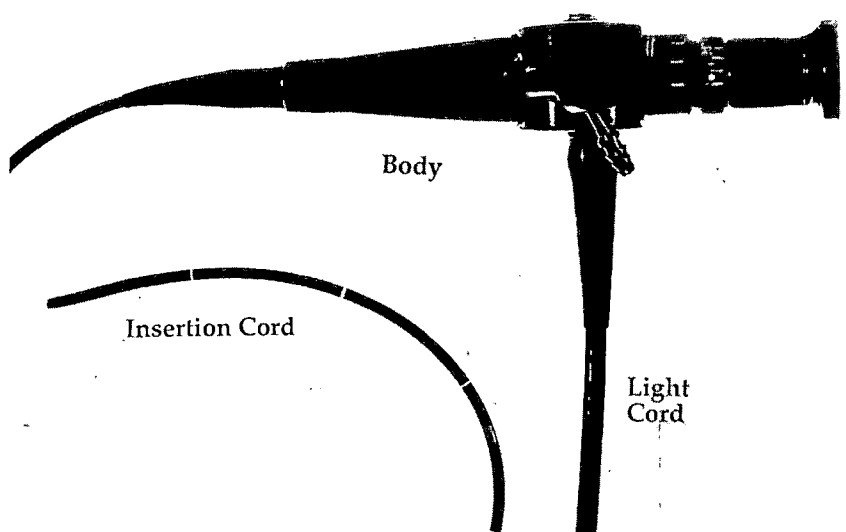


Figure 5. Photograph of the Olympus LF-1 fiberscope showing the three parts: 1) Body, containing the eyepiece, working channel opening, and the tip control (behind); 2) Insertion cord, containing the image and light guide bundles; 3) Light cord for transmitting light from the light source to the fiberscope.

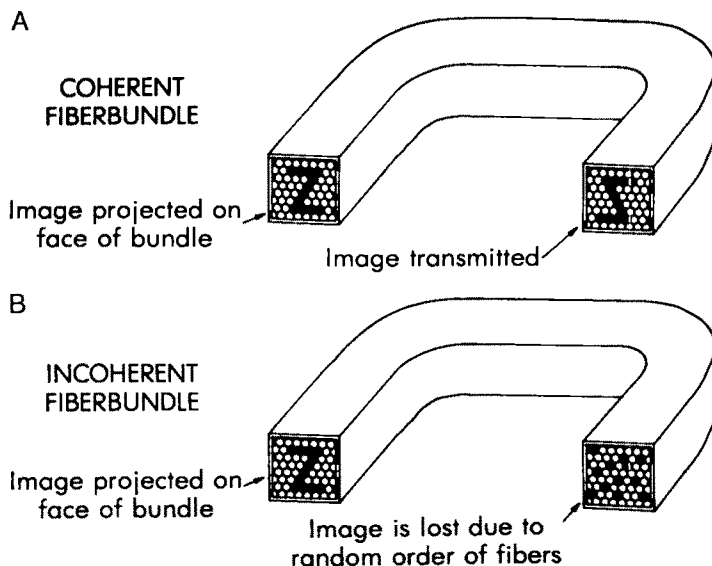


Figure 6. In a coherent fiberbundle the arrangement of fibers in one end of the bundle exactly matches the arrangement in the opposite bundle face (A). An incoherent bundle exhibits no correlation between the fiber arrangements in the two bundle faces. (From Tams T (ed): *Small Animal Endoscopy*. St Louis, The C.V. Mosby Company, 1990, p 7; with permission.)

transmission qualities of glass and the resistance of glass to deterioration, glass fibers are preferred for high-quality applications such as medical fiberoptics.

Excessive bending and acute angulation of the insertion cord will break individual fibers within the cord. Each broken fiber will appear as a black dot in the ocular piece. As more and more fibers are broken, the visual field will be distorted by the increasing number of black dots. The ultra thin endoscopes (e.g., Olympus PF-18M) are especially vulnerable to bundle fracture at the junction of the insertion cord and the body. In order to minimize the risk of bundle breakage, a short piece of plastic tubing can be placed on the scope at this junction point. This will prevent over-bending of the fiberscope.

Optical System

Because the actual image transmitted by the fiberoptic bundle is quite small (0.3 to 5 mm in diameter) the image must be magnified for the endoscopist by a lens system. An objective lens is placed at the distal end of the fiberscope; this lens forms an image on the distal end of the image bundle. Since the objective lens inverts the image the fiberoptic bundle is internally rotated 180 degrees which compensates for the image inversion (Fig. 7). Because the image projected by the objective lens is limited by the size of the image bundle, the image is then magnified by an ocular lens placed in the eyepiece.⁶ The eyepiece also contains a diopter adjustment to compensate for any visual abnormality of the endoscopist. The result is

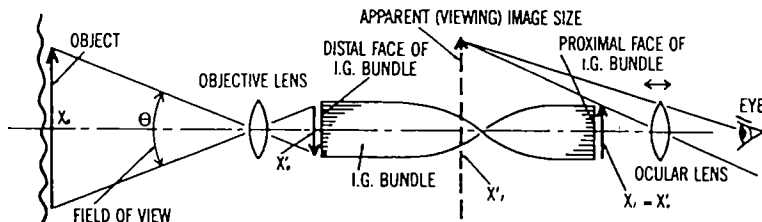


Figure 7. A basic fiberoptic optical system. I.G.-image guide. (From Kawahara I, Ichikawa H: *Fiberoptic instrument technology*. In Sivak MV, Jr (ed): *Gastroenterologic Endoscopy*. Philadelphia, W.B. Saunders Company, 1987, p 23.)

a well illuminated and magnified image of high resolution. The image presented at the eyepiece is a composite image that can be likened to the image formed on a television screen.⁹ Magnification does have a practical limitation in that with increasing magnification the individual fibers within the bundle are magnified, become visible, distort the object image.

The range of focus or depth of field is determined by the distance from the objective lens to the image bundle. For most fiberoptic laryngoscopes the depth of field is 3 to 50 mm. The practical significance of this is that the fiberoptic can be focused on objects between 3 and 50 mm from the tip of the scope.

In addition to the size and quality of the image, the field of view is also an important feature of the fiberoptic. A wider field of view permits a better visual field of orientation for the endoscopist. However, increasing the field of view decreases the size of the primary image. The proper combination of field of view and image size requires a set of compound lenses in the objective and illumination lenses at the distal end of the fiberoptic.

Mechanical System

The modern fiberoptic bronchoscope appears deceptively simple in construction, but in reality is a complex structure containing image bundles, illumination bundles, working channels, angulation control wires, and a flexible distal joint system, all ensheathed in a tough, durable outer covering (Fig. 8). The endoscope must have a certain degree of rigidity for easy passage but still have flexibility, particularly at the distal end, for smooth movement. The distal end of bronchoscopes and laryngoscopes have a two-way angulation system because they must be of a small diameter. Two-way angulation means that the tip can be deflected in two directions (up and down). In a two-way angulation system, movement of the tip to the right or left must be achieved by rotation of the proximal body of the scope. By combining up and down deflection with right and left rotation, movement of the tip in all four quadrants of the viewing field can be achieved. Because they can be of a larger diameter, gastroscopes and colonoscopes have four-way angulation systems, permitting movement in four directions with the hand controls of the fiberoptic body. The flexible section of the distal end of the fiberoptic is constructed of a series of metal bands attached together by flexible joints (Fig. 9). An angulation wire runs the length of the

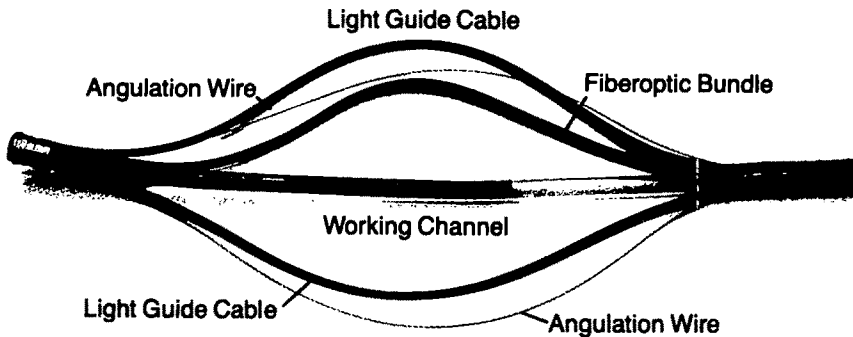


Figure 8. Inside of a fiberoptic bronchoscope insertion tube. Two angulation wires control the bending of the tip of the fiberscope. Two light guide cables contain fiberoptic bundles (incoherent), which bring light to the tip of the fiberscope. The fiberoptic bundle contains the coherent bundle, which transmits images from the objective lens at the tip of the fiberscope to the eyepiece of the fiberscope. The working or suction channel is used for suctioning of secretions and instillation of local anesthetics. (From Ovassapian A (ed): *Fiberoptic Airway Endoscopy in Anesthesia and Critical Care*. New York, Raven Press, 1990; with permission.)

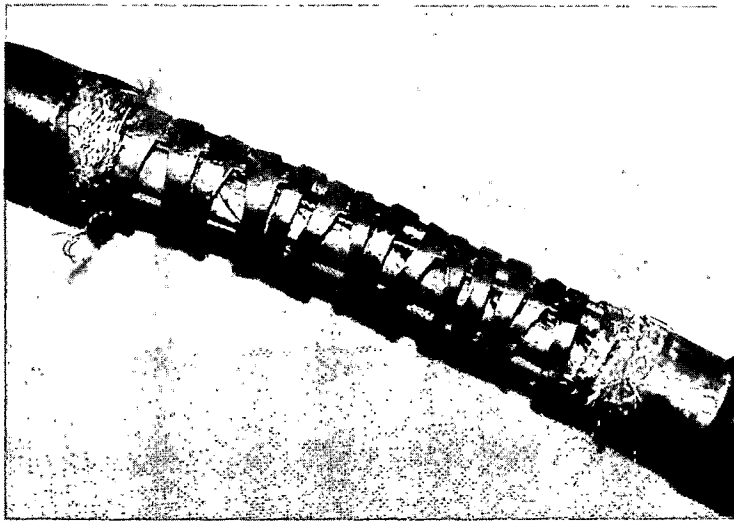


Figure 9. Photograph of the bending section of a colonoscope. The protective plastic and metal mesh coverings have been removed. This section is composed of a series of helical metal bands controlled by angulation cables. This fiberscope has four-way angulation control. Bronchoscopes usually have two-way angulation control.

fiberscope from the control knob through the metal bands and is fixed at the distal end of the endoscope. Tip deflection is produced by rotating the control knob, thus exerting tension on the angulation wire, which in turn flexes the metal bands (Fig. 10). When the fiberscope is extended, tip deflection occurs in the up and down directions when the control knob is manipulated. However, if the fiberscope is bent upon itself (flexed), tip deflection may occur at a 90° angle to the up and down plane. This altered directional response is most likely a result of internal twisting of the angulation control wire. This is of significance to the endoscopist because as the direction of tip deflection becomes unpredictable orientation is lost. There is considerable variation between fiberscopes as to the degree of altered movement that occurs. This variability is a function of the degree of stretching of the angulation control wire that occurs with use and aging of the fiberscope. The problem of altered tip deflection can be avoided if the fiberscope remains extended during endoscopy. Improvements in the engineering and construction of the angulation system in recent years have resulted in an increase in the degree of tip deflection and smoothness of manipulation.

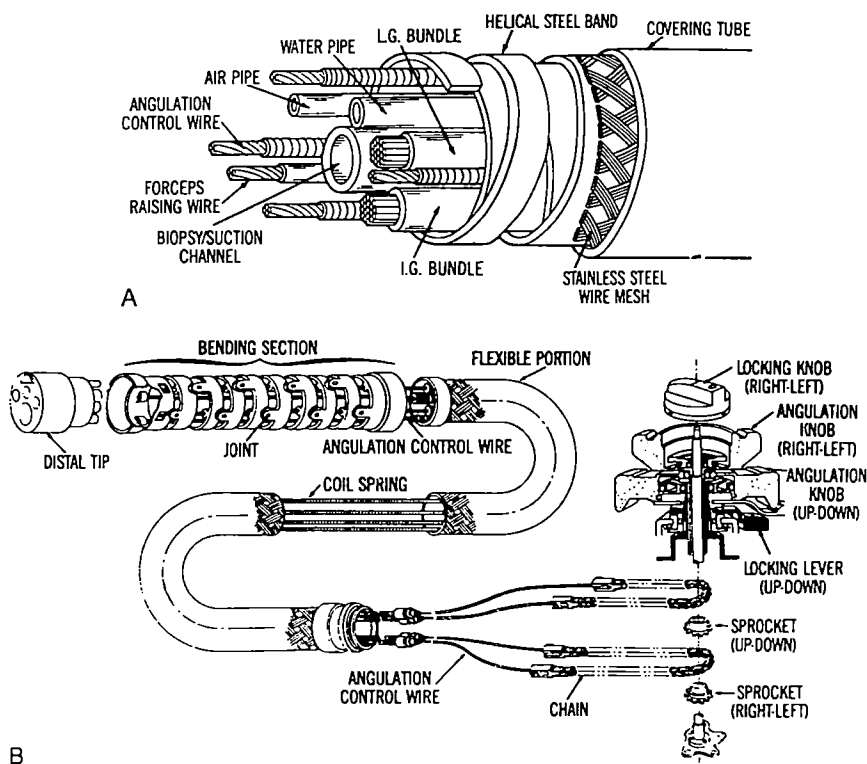


Figure 10. Bending section and angulation system of a fiberoptic endoscope. (From Kawahara I, Ichikawa H: Fiberoptic instrument technology. In Sivak MV, Jr (ed): Gastroenterologic Endoscopy. Philadelphia, W.B. Saunders Company, 1987, p 31.)

The working channel runs the length of the endoscope and can be used for a variety of functions (Fig. 11). Suction can be applied for clearing of secretions, and medications can be instilled into the airway. For routine tracheal intubation, insufflating oxygen at 4 to 7 liters per minute will keep the objective lens dry and clear of secretions. The working channel of most laryngoscopes is 1.2 mm in diameter. Suction applied to a channel this small is seldom as effective for clearing of secretions as oxygen insufflation. Working channels of bronchoscopes are 2 to 4 mm in diameter, which will accommodate suction for clearing of secretions as well as biopsy instruments for diagnostic procedures.

Light Sources

Two basic types of light sources are in widespread clinical use today (Fig. 12). A low-power halogen light source provides adequate illumination and is relatively compact and inexpensive. The halogen light source provides adequate illumination for still photography via the endoscope. High-power xenon light sources are also available, providing excellent illumination and they are necessary if a video image display is used. The xenon light source, however, costs five to ten times more than a halogen light source. The LG connector that inserts into the light source becomes quite hot and can produce a third-degree burn if it contacts the skin of the patient or the endoscopist. Care must be exercised after the light cord is detached from the light source so that an accidental burn does not occur. Some fiberoptic laryngoscopes that have the light source in the handle of the endoscope and use C batteries as a power source have been manufactured (Fig. 13). Although the laryngoscope is small, the illumination is poor and imaging is often inadequate. The production of a self-contained laryngoscopic unit may be feasible in the near future, but the illumination intensity must be increased.

Photographic Systems

A visual record of different phases of the tracheal intubation process may be required for teaching purposes or as part of the patient record. Patients that need frequent airway examination for therapeutic reasons or as a means of tracking the progress of a pathologic condition may require a

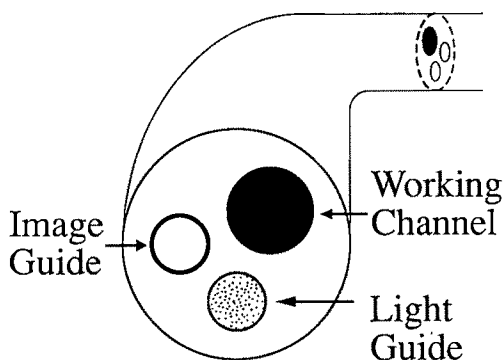


Figure 11. Internal components and construction of the insertion tube of the fiberscope. (From Kawahara I, Ichikawa H: *Fiberoptic instrument technology*. In Sivak MV, Jr (ed): *Gastroenterologic Endoscopy*. Philadelphia, W.B. Saunders Company, 1987, p 23.)



Figure 12. A, Halogen light source. (Olympus model CLK-3). This is the standard light source for fiberoptic laryngoscopy. B, Olympus xenon light source for fiberscopes. The cost of this unit is several times the cost of a halogen light source.

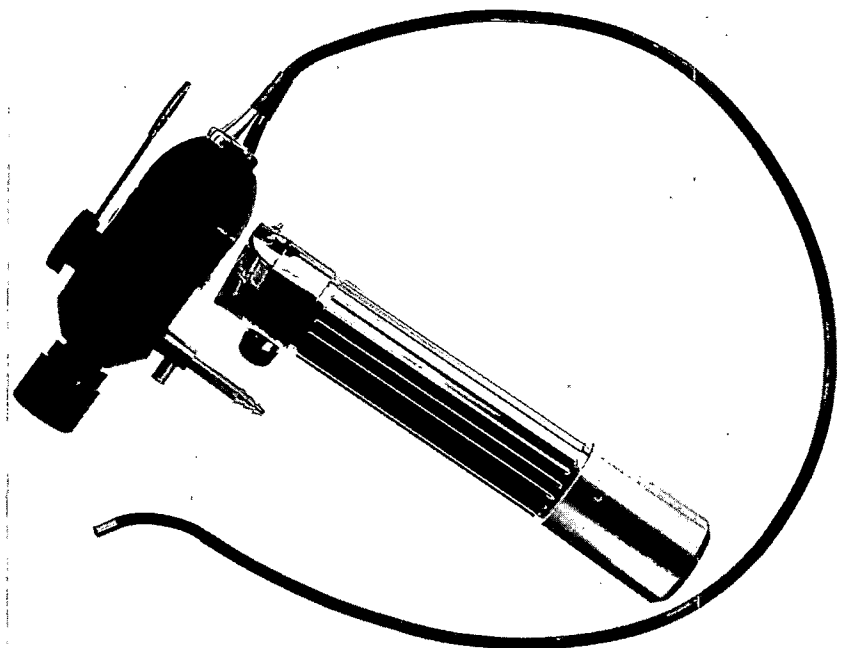


Figure 13. Photograph of a fibroscope with a self-contained light source. The handle contains three C batteries. Light intensity with this type of fibroscope is not nearly as great as with independent halogen or xenon light sources.

videorecording of the examination for future reference and comparison to subsequent examinations. Pentax and Olympus devices also have adaptors for 35-mm still cameras. The correct light source with a flash device is necessary for color photographs. Videotaping is also possible; video equipment, however, will more than double the cost of the flexible fiberoptic system. The increased investment may be acceptable for large teaching programs but is generally not cost effective for the private practitioner. However, many hospitals already have sophisticated endoscopic video equipment that may be adapted to the anesthesiologist's flexible fiberoptic laryngoscope. Currently near the completion of development are computer systems that store video images digitally. These systems may be quite useful for maintaining a record of endoscopic images.

TYPES OF FIBROSCOPES

A variety of medical-grade fiberoptic endoscopes are commercially available. The size of the endoscope and features depend upon the intended application. The diameter of the light and image bundles is actually quite small. Consequently, the size of the endoscope depends upon the additional components that are required (Fig. 14).

Gastrointestinal Endoscopes

A typical colonoscope contains 40,000 fibers and will be 12 to 20 mm in diameter. There are also a number of therapeutic procedures that can be performed with these devices. In addition to the illumination and imaging bundles, gastroscopes and colonoscopes have working channels for suction, air insufflation, and biopsy instruments. The diameter of these endoscopes is substantially greater than in endoscopes designed for the airway.

Airway Endoscopes

The number of ancillary components and ultimately the size of the airway endoscope depends on whether the scope is designed for diagnostic or therapeutic procedures. Bronchoscopes with an external diameter as small as 1.8 mm that will easily pass through a tracheal tube of 2.5-mm ID are available (Olympus PF-18M). Fiberscopes this small, however, have no directional control apparatus or working channels and are suitable for diagnostic purposes only. As directional controls and working channels are added, the diameter of the scope increases. The Olympus LF-P scope is only 2.2 mm in diameter and is designed for pediatric applications; this scope has a directional control mechanism, but no working channel. The standard adult laryngoscopes such as the Olympus LF-1 (4.0 mm diameter) or Pentax FI-10P (3.5 mm diameter) contain light guides, image bundles, two-way directional control, and one working channel. The Olympus LF-1 and the Pentax FI-10P are the predominant laryngoscopes in use by

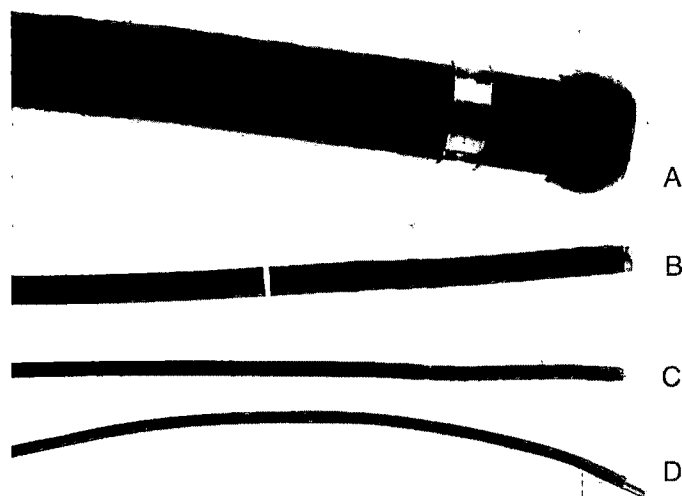


Figure 14. Photograph of the distal ends of four different fiberscopes. As more channels are added the diameter of the scope increases. A, Olympus CF colonoscope, 15 mm diameter; B, Olympus LF-1 laryngoscope, 4 mm diameter; C, Olympus LF-P pediatric laryngoscope, diameter 2.2 mm, two-way directional control but no working channel; D, Olympus PF-18M ultra-thin bronchoscope, no working channel and no directional control.

Table 2. *Specifications of Olympus LF-1 and Pentax FI-10P Flexible Laryngoscopes*

	LF-1	FI-10P
Angle of viewing field (degrees)	75	90
Range of tip deflection (degrees)	up-down 120	up-down 130
External diameter (mm)	4.0	3.5
Working length (cm)	60	60
Totally immersible	no	yes

anesthesiologists in the United States (Table 2). Both instruments are quite durable and function in comparable fashion. The differences are subtle and personal preferences by the endoscopist will determine which instrument is used. The FI-10P has a larger field of view (90 degrees versus 75 degrees for the LF-1) and a slightly greater range of motion. The larger field of view is secondary to the fact that the FI-10P has two LG bundles, whereas the LF-1 has one. The FI-10P is also totally immersible for cleaning purposes; the body of the LF-1 is not immersible. The LF-1 has been used extensively and is very durable. The LF-1 has external white markings every 5 cm, which some endoscopists find useful. The LF-1 is also slightly stiffer. Some endoscopists believe that the increased stiffness increases the ease of insertion of the LF-1, while others believe that the increased flexibility of the FI-10P enhances insertion. Both the LF-1 and the FI-10P are high-quality instruments that transmit a good image and with proper care will provide many years of reliable service for the anesthesiologist.

Flexible nasopharyngoscopes are of comparable diameter to flexible laryngoscopes. The nasopharyngoscopes, however, have a short working length (25 to 30 cm) and generally do not have a working channel (e.g., Machida ENT-3L and 4L [Machida, Orangeburg, NY]; Olympus ENF-P2 [Olympus Corp., Lake Success, NY]). Because of the short length these scopes are not suitable for tracheal intubation.

ADDITIONAL MEDICAL APPLICATIONS

Fiberoptic technology has many other medical applications besides flexible diagnostic endoscopy and tracheal intubation.⁵ Fiberoptic light and image transmission devices have been incorporated into rigid bronchoscopic instruments as well as flexible ones. The newer generations of rigid bronchoscopes (e.g. Storz bronchoscopic systems) use fiberoptic illumination devices. The advantages include excellent illumination and accurate image transmission with appropriate magnification. The high-intensity illumination provided by fiberoptic bundles permits magnification of the image. This equipment permits controlled diagnostic and therapeutic procedures via rigid endoscopy for infants and children as well as adults.

Optical fibers are also used for measurement of physiologic and chemical parameters. This type of device is composed of an optical fiber within a catheter that is inserted into the desired part of the body. At the distal end of the catheter is a miniature sensor (optode) and at the proximal

end is an optical processor. Light is transmitted via the fiber to the optode. Reflected light is then transmitted back to the processor. Physiologic alteration of the reflected light is processed and a measurement value determined. This technique can be used to measure arterial and intracranial pressures. For pressure measurement the sensor consists of a small tube at the distal end of the optical fiber; the end of the tube in contact with the patient is sealed with a reflective membrane. If the pressures are equal on both sides of the membrane, the light is reflected straight back through the optical fiber to the processor. Pressure changes will distort the membrane and alter the light reflection from the membrane. Blood velocity can also be measured with a fiberoptic apparatus. Blood velocity is determined when laser light is transmitted through a fiber and scatters off moving red blood cells. As the speed of the red cell increases, the wavelength of the reflected light decreases. The processor can analyze the wavelength differences and compute the blood velocity. Optical fibers are also used to measure the oxygen saturation of hemoglobin. Oxygenated hemoglobin reflects more red light than desaturated hemoglobin, whereas infrared light is reflected equally by saturated and desaturated hemoglobin. By transmitting both red and infrared light through an optical fiber in the blood, the total hemoglobin and ratio of saturated hemoglobin can be determined by analyzing the amount of reflection of red and infrared light. Optical sensors that can measure blood chemistries have also been developed. For many physiologic measurements fiberoptic systems are more sensitive, reliable, and less expensive to manufacture than microelectronic sensors.

One of the most promising applications of fiberoptic technology is transmitting laser energy inside the body for therapeutic procedures. The type of laser used depends on the therapeutic goal. For destruction of tissue, higher energy levels are required than for coagulation of blood and proteins. Significant technologic problems must be resolved in order to deliver the proper energy level to the tissue without heat damage to the fiberoptic guide. Laser applications have necessitated the use of materials other than glass for the manufacture of optical fibers. For example, quartz fibers are used for transmission of argon and YAG lasers. Research is continuing in the search for an efficient fiber that will transmit radiation from carbon dioxide lasers. Optical transmission of laser energy is being used for relieving obstruction of coronary arteries (laser angioplasty) and holds promise of much wider application in the near future.

SUMMARY

Fiberoptic endoscopes, seemingly simple devices, are complex instruments that required significant research and development to achieve the current level of sophistication. Fortunately for the medical profession, fiberoptic light transmission is an important principle with wide application in the communication industry. For this reason, research and development continues at a rapid pace. This research is then readily applicable to medical instrument technology. The benefit for the physician is a wide variety of reliable, high-quality fiberoptic instruments. The union of fiberoptic medical

technology with sophisticated video and computer equipment has enhanced our ability to diagnose, treat, and record pathologic conditions in many previously inaccessible areas of the body.

Fiberoptic endoscopy has become an integral part of anesthesiology practice as well. Anesthesiologists are now routinely using fiberscopes for tracheal intubation and examination of the airway. This equipment allows the anesthesiologist to manage patient airways that were extremely difficult to manage without fiberoptics. Fiberoptic technology will continue to be of increased importance in the practice of anesthesiology and critical care medicine. Knowledge of the principles of fiberoptics will aid in understanding its medical applications.

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Address reprint requests to

Stephen F. Dierdorf, MD
Professor of Anesthesiology
Indiana University School of Medicine
1120 South Drive
Fesler Hall 204
Indianapolis, IN 46202-5115

The Care and Cleaning of the Flexible Fiberoptic Bronchoscope

*Elizabeth C. Behringer, MD**

The flexible fiberoptic bronchoscope was first demonstrated in 1966, at the Ninth International Congress on Diseases of the Chest.¹⁶ Dr. Shigeto Ikeda and colleagues¹⁷ were the first to demonstrate and publish data on the use of the flexible fiberoptic bronchoscope. In the ensuing 25 years, the fiberoptic bronchoscope has become a mainstay in the diagnosis, treatment, and management in myriad pulmonary diseases.

The flexible fiberoptic bronchoscope is a relatively delicate and expensive instrument. An understanding of the basics involved in the operation and routine maintenance of the fiberoptic bronchoscope is essential for every bronchoscopist. This article reviews the basics of the care and handling of the fiberoptic bronchoscope. The way to clean, disinfect, and sterilize the fiberoptic bronchoscope is discussed as well. A thorough understanding of operation and maintenance will help to ensure the longevity of the equipment. More importantly, this knowledge will help to minimize risk to the patient, especially in the transmission of infectious agents.

ANATOMY

A flexible fiberoptic bronchoscope is made up of four contiguous sections. A long connector joins the body of the bronchoscope to the light source. The head or control section is connected to a flexible insertion shaft with a distal controlable tip. The control section has three components. An angle lever allows the distal tip to be rotated to varying degrees. The distal tip of the Olympus fiberoptic bronchoscope (Olympus Corp., Lake Success, NY) rotates up and down while the distal end of the Machida bronchoscope (Machida, Orangeburg, NY) rotates 30° to the right or left for ease of lateral maneuvering.²⁸ The head of the fiberoptic bronchoscope has an eyepiece

*Instructor in Anesthesia, Department of Anesthesia, Harvard Medical School; Director, Post Anesthesia Care Unit, Massachusetts General Hospital, Boston, Massachusetts

with a diopter adjustment ring. The control section contains a channel that serves several purposes. It acts as a channel to aspirate sputum, liquid, or other viscous material when connected to a suction vacuum. Additionally, the channel serves as an instillation port. Sterile saline may be instilled in order to help collect sputum or cytology specimens. Lastly, the channel allows for the instillation and withdrawal of biopsy forceps, cytology brushes, etc. Further details on the specifications are available in several sources.^{16, 28, 40}

STORAGE

An organized, well-stocked storage and maintenance area is imperative. This is particularly true when the procedure is performed as an emergency.

Flexible fiberoptic bronchoscopy is a procedure that may be performed in several areas of the hospital by a variety of personnel. At the Massachusetts General Hospital, flexible fiberoptic bronchoscopy is performed in many settings including the operating rooms, endoscopy suites, intensive care units, the emergency room, and the thoracic-surgery floor. A variety of physicians including general surgeons, cardiothoracic surgeons, anesthesiologists, pulmonologists, intensivists, and their residents and fellows are trained in using fiberoptic bronchoscopes.

As a member of the thoracic anesthesia and surgical intensive care unit teams, I perform flexible fiberoptic bronchoscopy frequently throughout the hospital at any time of the day or night. One of the goals of the team is to keep the bronchoscopy equipment in a convenient storage area that is well stocked and readily available to our thoracic surgeons, thoracic anesthesiologists, and intensivists. Thus, we have a centralized storage room located in the thoracic operating room area, fondly known as "Fort Knox."

Sterilized fiberoptic bronchoscopes are stored in a closet in the vertical or hanging position.²¹ Other methods of clean storage described include horizontal storage within the drawers of a mobile bronchoscopy cart⁷ or storage within the soft, molded foam of its carrying case. Whichever storage method is chosen, the clean bronchoscopes should be stored in an environment that ensures that the shaft is not bent.

Several bronchoscopy carts are available for use within the operating room setting. Mobile bronchoscopy carts allow for rapid, easy transport to distant locations where the bronchoscopy is being performed (Table 1). Mobile carts are stocked with the flexible bronchoscope, biopsy forceps, cytology brushes, and preferred light source of the attending bronchoscopist. A local kit containing an emesis basin, two packages of sterile 4 × 4 cm² sponges, two foil cups to hold solution and a 12-ml syringe is also supplied. Materials providing local anesthesia to the oro- and nasopharynx include 2% lidocaine solution and jelly, 4% lidocaine and 3% lidocaine-0.25% phenylephrine solution. Several cotton-tipped swabs and tongue blades are provided as well as a De Vilbiss atomizer (The De Vilbiss Co., Somerset, PA). An oral bite block and a Portex fiberoptic swivel adapter (Portex Incorporated, Wilmington, MA) are standard equipment along with tonsil tip and long, sterile plastic suction catheters, sputum traps, and

Table 1 *Contents of a Mobile Bronchoscopy Cart*

BARRIER PROTECTION	LOCAL ANESTHESIA KIT
Sterile gown	2% Xylocaine solution
Sterile disposable gloves	2% Xylocaine jelly
Goggles	4% Xylocaine solution
Mask	3% lidocaine 0.25% phenylephrine solution
	De Vilbiss atomizer
INSTRUMENTS	MISCELLANEOUS
Flexible fiberoptic bronchoscope	Emesis basin
Light source	Sterile sponges
Biopsy forceps	12-ml syringe
Cytology brushes	Foil cups
	Cotton-tipped swabs
AIRWAY EQUIPMENT	Tongue blades
Oral bite block	Silicone lubricant
Portex fiberoptic swivel adapter	
Nasal cannula	
SUCTION EQUIPMENT	
Tonsil tip (Yankauer) suction catheters	
Sterile plastic suction catheters—sizes 10 French and 14 French	
Sputum traps	
Suction tubing (extra)	

silicone lubricant. Simple barrier protection used during the procedure includes a sterile gown, disposable gloves, goggles, and a mask. A vacuum suction set-up is available on every floor. An emergency resuscitation cart should be immediately available during this procedure. Standards of patient monitoring during anesthesia have been adopted by the Harvard Medical School and American Society of Anesthesiologists.⁸ We adhere to these standards in all fiberoptic bronchoscopic procedures involving an anesthesiologist (Table 2).

Table 2. *Emergency Equipment and Monitoring for Fiberoptic Bronchoscopy*

AIRWAY	CIRCULATION
Ambu-bag mask device and tubing	Blood pressure
Intubation equipment	a) Invasive-arterial line
a) Laryngoscope and blades	b) Noninvasive
b) Endotracheal tubes	Electrocardiogram—heart rate and rhythm
c) Stylets	Resuscitation cart
d) Magill forceps	Example of available drugs
Oral airways	Atropine
Nasal airways	Albuterol
	Ephedrine
BREATHING	Epinephrine
Pulse oximetry	(including racemic epinephrine)
Nebulizer mask	Lidocaine
	Naloxone
	Phenylephrine

HANDLING

The nature and frequency of complications following the procedure is discussed in several excellent reviews.^{1, 2, 4, 14, 18, 25, 26, 29} The type of complications that may occur during the routine handling of the fiberoptic bronchoscope is reviewed in several sources as well.^{7, 35, 40} The fiberoptic bronchoscope as a relatively delicate instrument can malfunction frequently and need repairs. The following includes a few simple guidelines for the routine handling of the flexible fiberoptic bronchoscope. The key to successful use of the bronchoscope is to read the accompanying instruction manual thoroughly and keep it readily available. The light source should be cleaned regularly and kept free of dust. Dust can clog the channel of the bronchoscope. To keep the bronchoscope free from dust and debris between repeated uses, such as during a thoracic surgical procedure, it may be advisable to cover the equipment with a clean drape.

To avoid the risk of overheating, do not pile equipment on top of the light source. Heavy objects should not be placed on the bronchoscope. Also, the fiberoptic bronchoscope should not be autoclaved.

To keep the awake patient from biting down and damaging the fiber bundles, a bite block should be used during the transoral insertion of the fiberoptic bronchoscope. The distal tip of the bronchoscope should not be angled during insertion through an endotracheal tube. Do not force the bronchoscope through anything! To avoid stripping the covering off the shaft, the bronchoscope should be advanced gently through all double lumen or single lumen endotracheal tubes, as well as the tracheobronchial tree.

Suction should not be used while biopsy forceps or cytology brushes are in the channel. Nor should the biopsy forceps and brushes be advanced through the suction channel or the distal tip with undue force. If they are worn, frayed, or bent excessively, they should be discarded. This will avoid breakage of the biopsy forceps or brushes within the channel of the bronchoscope or the tracheobronchial tree of the patient. The biopsy forceps should be inserted through and withdrawn from the suction port in the closed position only. When the distal tip of the fiberoptic bronchoscope is angled acutely, the forceps or brush should not be passed through the tip. This will avoid damage to the suction channel, guide wire, forceps, and brush. Instead, the biopsy and brush tools should be advanced through the straightened distal tip of the fiberoptic bronchoscope. The tip is then ready to angle into position safely.

Silicone lubricant should be used only on the shaft of the fiberoptic bronchoscope to ease insertion through an endotracheal tube. Lubricant will cloud the viewing lens on the distal tip. Warm, sterile saline solution is helpful for defogging the viewing lens during flexible fiberoptic bronchoscopies.

CLEANING AND STERILIZATION

Universal precautions have been adopted in many institutions to help reduce the risk of the inadvertent transmission of disease. The routine

cleaning and sterilization of flexible fiberoptic bronchoscopes between each patient is an integral part of the maintenance of universal precautions and safe clinical practice (Table 3). This may be difficult because the design of the fiberscope makes access difficult for routine manual cleaning. The components of the fiberscope are fragile and will not withstand autoclaving. Ethylene oxide gas sterilization is an acceptable technique.^{21, 33, 40}

Fiberscopes may be sterilized by this method at a temperature of 130°F (54.4°C), pressure 20 psi, and humidity 50% for a period of 4 to 5 hours.⁷ The drawback to using this technique is that it is time consuming.

The cleaning and sterilization of fiberoptic bronchoscopes should be undertaken by trained personnel who understand the implications and importance of the routine use of high standards of hygiene. The instrument should be cleaned immediately after the procedure is completed in order to remove any inspissated sputum or tissue. Routine manual cleaning of the fiberscope also prepares it for effective sterilization. The proximal end of the suction port should be connected to a suction device. Subsequently, 100–200 ml of detergent solution is aspirated through the channel. The suction channel should be cleared with a cleaning brush as well. The shaft and the valves of the fiberscope are then cleaned with a sterile sponge soaked in soap solution. The shaft of the fiberscope is wiped from the proximal toward the distal end. Finally, cleaning is completed by rinsing the valves and shaft and aspirating approximately 200 ml of sterile water through the suction channel. Sterile water is used because tap water may be contaminated.^{11, 13} Guidelines for cleaning individual fiberscopes are generally available in the manufacturer's instruction manual.

The Morbidity and Mortality Weekly Review (MMWR) recommended that instruments in contact with sterile tissue, the vascular system, or mucous membranes, be sterilized prior to reuse.²² The process of sterilization implies the elimination of all viable microbial forms. Bacteria, mycobacteria, fungi, and viruses including the hepatitis B virus and HIV, the human immunodeficiency virus, are all potential respiratory pathogens.¹² These may be transmitted to respiratory equipment with the potential for cross-contamination of patients and medical personnel if rigorous cleaning, disinfecting, and sterilization techniques are not performed vigilantly.

Several reports have been published highlighting the contamination of fiberoptic bronchoscopes with a variety of respiratory pathogens.²⁴ *S. marcescens* has been implicated in two reports.^{32, 37} Webb and Vall-Spinosa³⁷ reported an outbreak of pulmonary infection due to *S. marcescens* in two intensive care units. The biopsy channel of the common fiberoptic bron-

Table 3. Routine Cleansing of the Fiberscope

CLEAN THE FIBERSCOPE AS SOON AS POSSIBLE AFTER THE COMPLETION OF BRONCHOSCOPY

Step 1:	Connect suction port to vacuum suction
Step 2:	Aspirate approximately 200 ml detergent solution through suction channel
Step 3:	Clear suction channel with cleaning brush
Step 4:	Wipe shaft and valves with detergent-soaked sponge
Step 5:	Aspirate approximately 200 ml sterile water through suction channel
Step 6:	Wipe shaft and valves with sterile water
Step 7:	Proceed with disinfection/sterilization

choscope yielded the organism. Weinstein et al³⁸ reported contamination and repeated bacterial culture of a *Proteus* species through the suction channel. Hussain¹⁵ reported a series of bronchial cultures positive for *Pseudomonas* species due to the inadequate sterilization of the suction attachment. Goldstein and Abrutyn¹⁰ reported contamination of a fiberscope by a *Bacillus* species. Bottone reported an outbreak of *Klebsiella* pneumonia due to a contaminated fiberscope.³

Several authors review the contamination of fiberscopes with *Mycobacterium tuberculosis* and other varieties of mycobacterium.^{5, 20, 23, 27, 34, 39} Schleupner and Hamilton³¹ described a pseudoepidemic of pulmonary fungal infection due to fiberoptic bronchoscopy. Hepatitis B virus and the HIV virus have reportedly been retrieved from bronchoscopes used on patients with the acquired immunodeficiency syndrome.¹² Thus, the potential for the transmission of HIV during fiberoptic bronchoscopy theoretically exists.¹³

Several authors describe techniques of the disinfection of fiberscopes.^{6, 7, 9, 19, 30, 36} The review of Hanson and Collins¹² aptly summarizes a rigorous routine of bronchoscopic hygiene including immediate cleaning of the bronchoscope and valves with detergent solution followed by 20 minutes of disinfection with either 2% alkaline glutaraldehyde (Cidex, Asep or Totacide) or succine dialdehyde (Gigasept) solutions. The disinfectant is rinsed, then the channel is flushed with 70% alcohol. This routine is purported to eradicate virtually all respiratory pathogens.

In addition to our rigorous cleaning techniques, we have used an automated, self-contained, sterile processing device (Steris System 1, Steris Corporation, Painesville, OH) that sterilizes fiberoptic bronchoscopes with a sporicidal, bactericidal, virucidal, fungicidal, and tuberculocidal solution (Steris 20). The turnover time after thorough cleaning is 20 minutes. We have found this to be reliable and efficient in a busy thoracic surgical group that performs several flexible bronchoscopies daily. In addition, we use single-use, disposable cytology brushes. In order to sterilize reusable biopsy forceps, gas sterilization is done after thorough cleansing. Infection control during fiberoptic bronchoscopy is an important topic worth detailed review. The adoption of rigorous standards of simple barrier protection, cleaning and sterilization for each patient is mandatory.

CONCLUSION

Familiarity with the construction, routine handling, cleaning, sterilization, and storage of the flexible fiberoptic bronchoscope is mandatory. This helps to ensure safe clinical practice and avoids unnecessary expensive repair of bronchoscopic equipment. Familiarity with the precise construction and methods of handling the fiberscope ensures its longevity as well. Rigorous standards for cleaning, disinfecting and sterilizing should be adopted by all personnel handling bronchoscopic equipment. This will help to avoid potential cross-contamination with numerous respiratory pathogens.

ACKNOWLEDGMENTS

The author would like to thank Mary Jo Dwyer, Julie Gifford, RN, and Madeleine Spadea, RN for their invaluable assistance in the preparation of this manuscript.

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Address reprint requests to

Elizabeth C. Behringer, MD
Department of Anesthesia
Massachusetts General Hospital
32 Fruit St.
Boston, MA 02115

Ancillary Fiberoptic Equipment

*Mary Kraft, MD**

Nothing defeats a successful fiberoptic intubation like a failing light source or plugged suction channel. This article describes those ancillary factors that are needed to ensure that the manipulation of the fiberoptic scope will result in success.

PORTABLE CARTS

As a hospital's most skilled manager of a patient's airway, the anesthetist is expected to be prepared at all times to manage the airway of a patient in respiratory difficulty in sections of the hospital remote from the operating room suite. In addition, a second skilled or knowledgeable individual may not be available to help the anesthetist fetch equipment or drugs at any time. Thus, self-sufficiency is a goal that can be readily achieved using a portable fiberoptic laryngoscope cart, as shown in Figure 1, to organize all equipment necessary for airway management.

As outlined in Table 1, this cart is capable of storing a clean fiberoptic laryngoscope, light source, and pulse oximeter, in addition to other ancillary equipment. It is compact and easily rolled down a crowded corridor or into an elevator. It may be fitted with an E cylinder of oxygen and a portable suction apparatus, so that all that is needed at the bedside is an electrical outlet.

ELECTRICAL NECESSITIES

While on the subject of electrical outlets, it is important to note the difference between the standard spark-proof outlets in the operating room and the three-pronged outlets in other locations. Adapters are often difficult to find when time is critical, so one should be securely fastened to the portable cart for instant use.

*Instructor in Anesthesia, Harvard Medical School; Assistant Anesthetist, Department of Anesthesia, Massachusetts General Hospital, Boston, Massachusetts

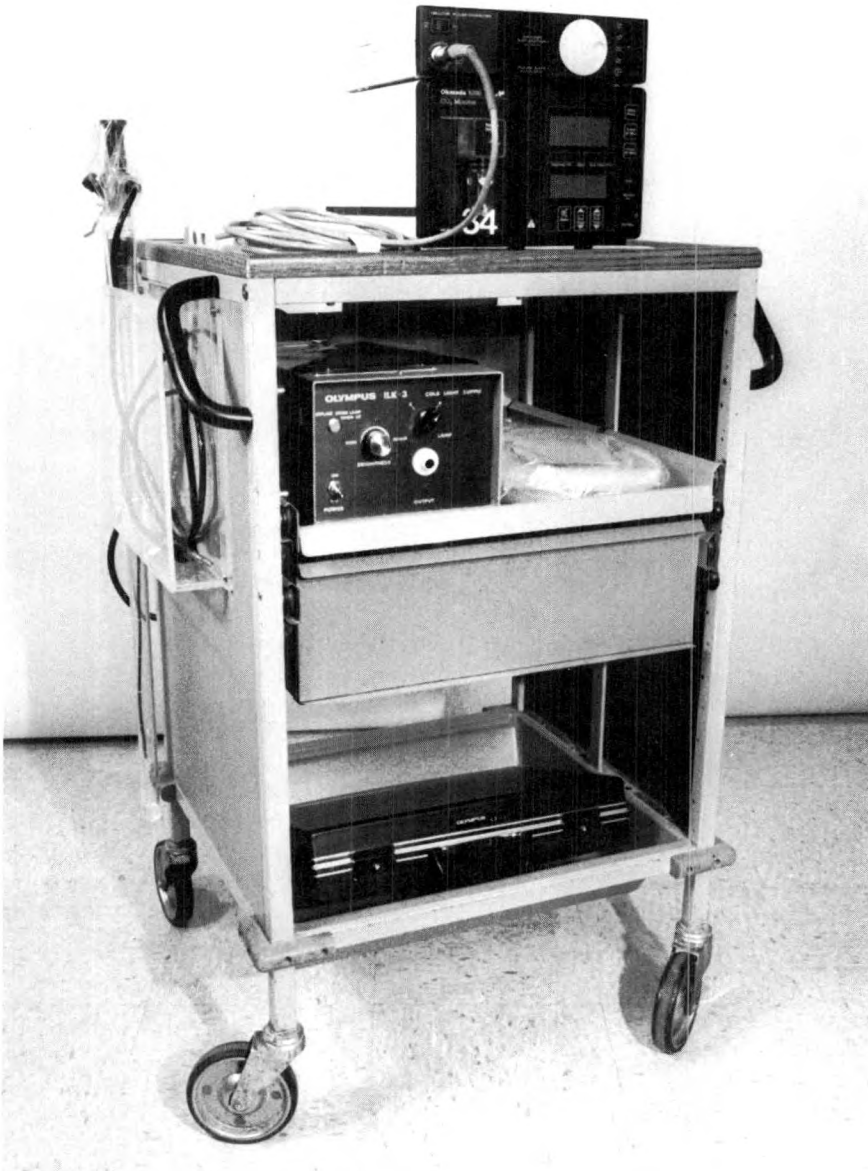


Figure 1. The intubation cart shown contains a sterile fiberoptic (wrapped in sterile plastic), drawers for airways, endotracheal tubes, etc. and a Nellcor oximeter on top of the cart. Underneath on a shelf, note the fiberoptic light source. A small oxygen cylinder may also be easily attached for back-up oxygen. The new standard of care involves checking proper endotracheal tube placement with a CO_2 analyzer (not shown).

Table 1. *Items for Cart*

Drawer	Contents
Airway Management	Oral airways Olympus bite blocks, etc. Conventional laryngoscope with assorted blades Green oxygen tubing Suction catheters and tonsil-tips, spare suction tubing Spray bottles for topical anesthetics Small, medium, and large masks Assortment of endotracheal tubes Cotton-tip applicators
Drugs	Atropine, glycopyrrolate Succinylcholine Lidocaine, ointment and spray Lidocaine ampules for injection Phenylephrine (Drugs for sedation should not be stocked routinely, but rather carried to the scene by the responsible anesthetist)
Miscellaneous items	Spare or backup lightbulbs Spare electrical adapter Pulse oximeter probes Three-way stopcocks Extension cord Pulse oximeter probes Capnograph adapters
Chained (or bolted) to outside of cart	Light source Pulse oximeter Capnograph Bracket for E-cylinder of oxygen with attached flowmeter Portable suction machine Cylinder for storing clean fiberoptic laryngoscope Cylinder for storing dirty scope

A back-up light bulb or two, or a twin light source is an additional necessity for fiberoptic preparedness. The most common time for the light bulb to burn out is when the light source is turned on with the initial power surge. It is highly recommended, therefore, that before any other preparations are made for fiberoptic laryngoscopy (and certainly before the induction of anesthesia), the laryngoscope be connected to the light source, turned on, and tested.

The light source itself should be compatible with the laryngoscope connector, and should be capable of generating sufficient wattage. Reserving a light source solely for use with the laryngoscope helps ensure its ready availability (especially if it, too, is bolted to the cart), and preserves its functional capacity, as it is less likely to be dropped or used by inexperienced personnel or for a prolonged period of time per use.

OXYGEN AND SUCTION

These twin pillars of anesthetic practice should not be forgotten as one contemplates fiberoptic intubation. Although there is a "suction" port on most fiberoptic laryngoscopes, I have found this channel to be much more useful as a conduit for oxygen.

Suctioning secretions through the port quickly blocks it unless scrupulous attention is paid to thoroughly cleansing it after each use. On the other hand, delivering a high flow of oxygen (5 to 7 liters) not only keeps the channel patent, but blows secretions out of the way making for better visibility. In addition, even apneic patients remain oxygenated as the flow is aimed toward the trachea with the laryngoscope.

Oxygen may be delivered to the laryngoscope by either directly attaching green oxygen tubing to the suction port or interposing a three-way stopcock, so that suction may be used if absolutely necessary. The other end of the green tubing may be attached to any oxygen source, i.e., wall flowmeter, anesthesia machine, or portable cylinder.

If, despite oxygen flow through the laryngoscope, secretions are a problem, a tonsil-tip or suction catheter may be used to suction the mouth around the laryngoscope. It is helpful in this instance to have an assistant suction the mouth while the anesthetist remains in control and looking through the laryngoscope.

STORAGE OF FIBEROPTIC INSTRUMENTS

In order to be available for immediate use, fiberoptic laryngoscopes should be stored clean. Routine cleaning after every use also helps preserve the life of the laryngoscope by maintaining patency of the suction/oxygen channel. The cleaning regimen at Massachusetts General is described in another article in this issue.

To prevent the fiberoptic bundles from being bent or broken, the laryngoscope is stored straight in a cylindrical tube on the portable cart.

MONITORING FOR LARYNGOSCOPY

It is our standard of practice that all patients who receive an anesthetic have electrocardiogram, blood pressure, and oxygen saturation monitoring, as well as a freely running intravenous catheter. We believe these basics essential for the patient undergoing awake fiberoptic laryngoscopy, regardless of the setting.

If pulse oximetry is not widely available throughout the hospital, one should strongly consider mounting such a device to the laryngoscopy cart. Useful, though not essential, would be a portable capnometer for additional confirmation that the endotracheal tube has not been dislodged during laryngoscope removal and taping of the endotracheal tube.

ENDOTRACHEAL TUBES

With the increasing availability of small-diameter fiberoptic laryngoscopes, the anesthetist has a wider choice of endotracheal tube sizes. As with direct laryngoscopy, the choice may be made on the basis of the patient's airway rather than the diameter of the laryngoscope. For most patients, any appropriately sized low pressure cuff endotracheal tube will suffice. However, patients who present with anatomical anomalies and/or for whom a nasotracheal intubation is planned may be more easily intubated with an endotracheal tube one-half to one size smaller than usual.

Endotrol tubes are quite useful for patients with severe fixed cervical flexion deformities, such as in ankylosing spondylitis. The internal wire allows the endotracheal tube enough flexion to be threaded into the most anterior larynges.

Although not commonly used for the placement of a double-lumen endotracheal tube, the fiberoptic laryngoscope is easily passed through the lumen to confirm its position in the correct mainstem bronchus.

SPECIAL AIRWAYS

There are at least four special airways commercially available for use with the fiberoptic endoscope. These help prevent trauma to the laryngoscope from the patient's teeth.

The most commonly available such airway is the Olympus bite block (Fig. 2). Its large internal diameter makes it possible to use it with a variety of endotracheal tubes. Its short length makes it comfortable for use with the awake patient and allows the laryngoscopist the most leeway in positioning the laryngoscope within the mouth. This asset can also be a liability, as it is not useful as a guide for the laryngoscope.

Another drawback to the use of the bite block is that the endotracheal tube-to-Y piece connector must be removed before the endotracheal tube is placed over the laryngoscope. After the endotracheal tube is in place,

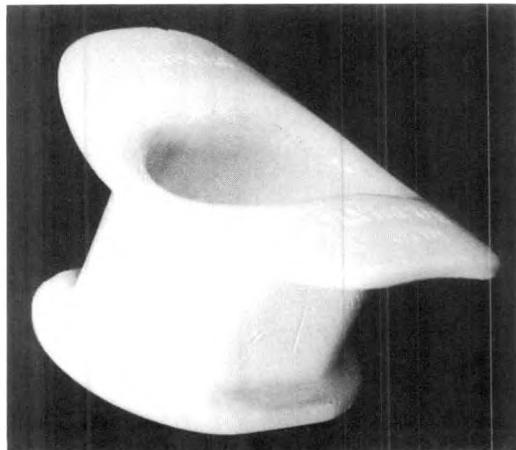


Figure 2. The Olympus bite block serves to protect the fiberoptic endoscope from the teeth but is not intended to guide the fiberoptic endoscope.

the bite block is removed over the tube and the connector reattached. During this maneuver, one must be careful to avoid dislodging the tube.

The Williams airway (Fig. 3) presents the same problem in manipulating the connector. However, its longer tongue piece serves as more of a guide around the tongue. When using this airway, one must take special care that it is positioned exactly in the midline, or it will guide the laryngoscopist away from the glottis. In addition, its longer curvature increases the likelihood of a dislodged tube as it is manipulated during its withdrawal. While it is certainly possible to use this airway during the course of an anesthetic, it would not be comfortable in an awake patient, so that it would have to be removed at some point if postoperative intubation is planned.

The Ovassapian airway (Fig. 4) physically resembles the Williams airway in length and curvature, and thus presents similar problems. Its advantage, however, is the dorsal openings that allow it to be removed without sliding it over the endotracheal tube. Thus, the connector may be left securely in place on the endotracheal tube at all times. Also, see the Patil mask (Fig. 5).

DRUGS

An in-depth discussion of the pharmacology of drugs useful for fiberoptic laryngoscopy is beyond the scope of this article. However, a short review of how common drugs are used for this purpose is presented here

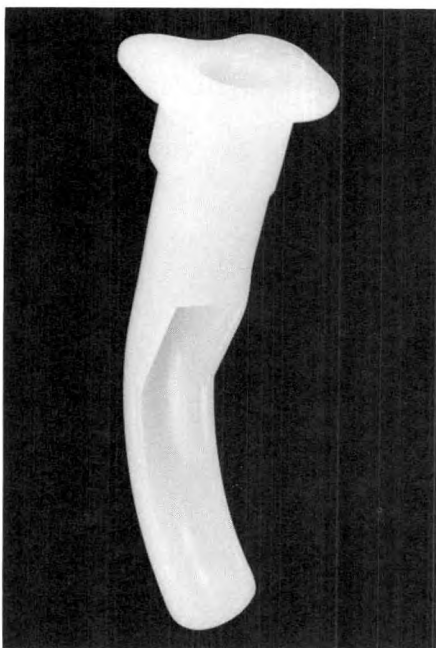


Figure 3. The Williams airway guides the fiberscope and protects the fiberscope from injury by the teeth.

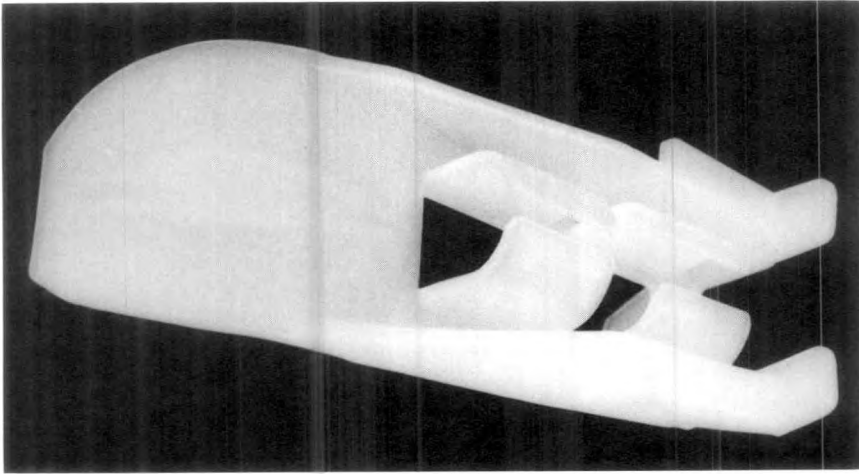


Figure 4. The Ovassapian airway guides the fiberscope, prevents damage to the fiberscope by the teeth, and also may be easily dislodged from the mouth after intubation without removing the endotracheal tube adapter.

as both a guideline and suggestion for what might be stocked in the portable laryngoscopy cart.

Anticholinergics

Secretions are a major deterrent to successful fiberoptic laryngoscopy. Therefore, a “drying” dose of an anticholinergic (e.g., atropine, 0.4–0.6 mg/70 kg or glycopyrrolate, 0.2–0.4 mg/70 kg IM) is a good addition to other preanesthetic medications. Patients are quite understanding of a dry mouth when its necessity is explained ahead of time.

Because patient cooperation is essential for “awake” laryngoscopy, scopolamine, with its unpredictable tendency toward disorientation, should probably be avoided in these patients.

Sedatives

Sedatives that also produce amnesia, such as diazepam or midazolam, not only produce the desired effect of sedation, but make the memory of an awake laryngoscopy almost nonexistent. Caution should be exercised when these drugs are used in association with narcotics for awake laryngoscopy, as their effects are synergistic and too much may rapidly produce unwanted apnea.

They should be titrated to effect (slurred speech is a good endpoint) in small incremental intravenous doses, over a period of about 15 minutes. While waiting for their onset, the anesthetist can be applying topical anesthesia to the mouth and/or nose.

Local Anesthetics

Although more comfortable than direct laryngoscopy, awake oral fiberoptic laryngoscopy still requires the mouth, oropharynx, glottis, and subglottic areas to be well anesthetized. (Of course, the nose needs to be well



Figure 5. The Patil mask has an adapter through which a flexible fiberoptic laryngoscope and endotracheal tube may be introduced. The mask permits ventilation of the patient during the intubation process.

anesthetized before contemplating a nasal intubation.) This may be accomplished by topical anesthesia with a drug such as lidocaine or a combination of topical anesthesia to the tongue and superior laryngeal nerve block and/or transtracheal administration of lidocaine.

General Anesthesia

Fiberoptic laryngoscopy can be performed with relative ease on a patient having a general anesthetic, as long as the following cautions are kept in mind.

1. As the patient under a general anesthetic has lost the ability to maintain his own airway, a second pair of hands is often necessary to help elevate the mandible and thrust it forward.
2. Patients breathing spontaneously under a general inhalational anesthetic still have reactive vocal cords, and may have laryngospasm as the laryngoscope is advanced towards the glottic opening, thus obscuring the view.
3. The patient who has received a full dose of a neuromuscular blocking

drug will not be able to oppose his vocal cords, eliminating laryngospasm as an impedance to intubation. The risk of hypoxia is lessened if oxygen is constantly flowing through the suction port, and careful attention is paid to the pulse oximeter reading. In general, attempts at intubating a fully relaxed patient should probably be kept to under 2 minutes.

Neuromuscular Blocking Drugs

Any of the neuromuscular blocking drugs currently available are suitable for producing relaxation for fiberoptic laryngoscopy. A succinylcholine bolus should suffice for the experienced user, but a drip, while somewhat slower in onset, provides more even relaxation for a longer period of time. This technique allows for more leisurely teaching of fiberoptic skills. Another advantage of succinylcholine is its rapid metabolism should the procedure need to be aborted soon after induction.

Of the nondepolarizing muscle relaxants, a medium- to short-acting drug with a minimum of cardiovascular side effects (such as atracurium or vecuronium) may be preferred, both for cardiovascular stability and the shorter time and relative ease of reversal, should this become necessary.

SUMMARY

To be successful at fiberoptic intubation, the anesthetist must have a clean, functioning fiberoptic laryngoscope and a well-organized assortment of ancillary equipment readily at hand. A portable cart containing the items outlined in this chapter is a way of assuring the availability of all necessary items at a moment's notice, ready for use in the remotest corners of the hospital.

Address reprint requests to
Mary Kraft, MD
Department of Anesthesia
Massachusetts General Hospital
32 Fruit Street
Boston, MA 02114

Anatomy and Patient Positioning for Fiberoptic Laryngoscopy

*James T. Roberts, MD**

Even though one performs a cursory examination of the contents of the oral cavity during each direct oral laryngoscopy performed with a Macintosh or Miller laryngoscope, the anatomy of the area should be reexamined prior to performing fiberoptic laryngoscopy. The anatomy is viewed from a different vantage point during fiberoscopy, i.e., indirectly and from a few centimeters away. Correct patient position depends on whether a direct or fiberoptic technique is to be used.

NASAL PASSAGES

The nasal passages are bounded anteriorly by the external nares and separated by the nasal septum which is composed of five bones and cartilage; the ethmoid, vomer, columella, maxilla and palatine. Laterally, the nasal passages are bordered by three nasal turbinates (the superior, middle and inferior) and occasionally a fourth (supreme). The inferior turbinate articulates with four bones (the ethmoid, lacrimal, maxilla and palatine). The middle turbinate is a process of the ethmoid bone and articulates with four others (the lacrimal, sphenopalatine, maxilla and inferior turbinate). While the superior turbinate is also an extension of the ethmoid, it is much smaller than the inferior or middle turbinates and does not lie directly in the path of the fiberscope or endotracheal tube as do the latter. It is primarily the inferior turbinate that limits passage of a nasotracheal tube. The laryngoscopist should begin looking through the fiberscope immediately once the tip of the fiberscope passes the external nares. The fiberscope may then be navigated through the nasal passages with minimal tissue damage. The rich vascular membrane covering the turbinates is easily damaged during nasal intubation and should be protected as described in another article in this issue.

Five nerves (sphenopalatine ganglion, infraorbital, anterior superior alveolar, olfactory and maxillary) innervate the lateral wall of the nasal

*Professor, Department of Anesthesia, Massachusetts General Hospital, Boston, Massachusetts

passages (Figure 1). Three nerves (olfactory, anterior ethmoid, and nasopalatine) innervate the nasal septum (Figure 2). With so many nerves involved with sensation to the nasal passages, topical anesthesia must be widespread, and not merely applied to the sphenopalatine ganglion.

ORAL CAVITY

The teeth represent the first formidable barrier to oral fiberoptic laryngoscopy. Mandibular movement may be so limited that insertion of the fiberscope is just possible. The teeth also represent a significant threat to the fiberscope during laryngoscopy. Prior to bite blocks designed for fiberoptics, lifting the mandible would press the teeth against the fiberbundle and frequently damage the coherent bundles. Pressure by the teeth would also limit the ability to advance or withdraw the fiberscope. The invention of bite blocks (Ovassapian, Patil, Williams) overcame these problems. The mandible could then be lifted without fear of damaging the fiberscope or limiting insertion or withdrawal. Photographs of the individual bite blocks are included in another article in this issue.

The tongue is the next obstacle in the fiberscope pathway. Moisture from the tongue may immediately coat the distal lens necessitating withdrawal and cleaning. Prior to the use of bite blocks, the tongue was pulled forward, out of the mouth, by an assistant. This lifted the base of the tongue from the posterior pharyngeal wall, opening a path for the fiberscope. Frequently, however, the frenulum of the tongue was caught and injured in the space separating the two lower incisors.

A clever way to separate the tongue from the posterior pharyngeal wall is to have the patient sit upright. Awake intubation, described in Reed

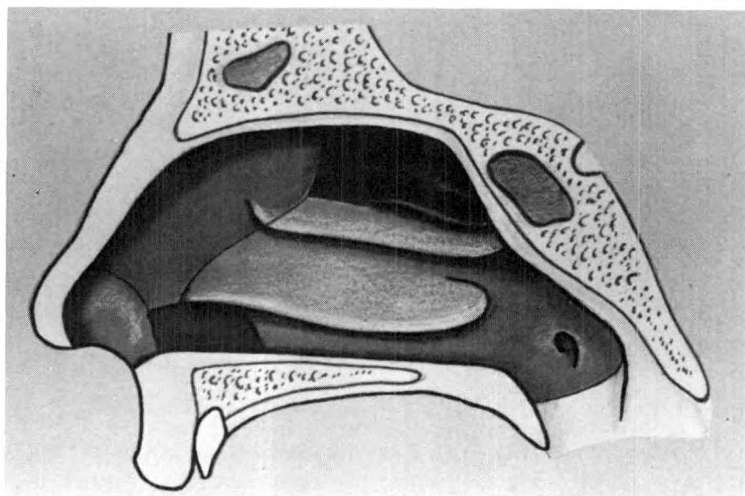


Figure 1. Sensory distribution of the lateral nasal wall. (From Roberts JT: *Fundamentals of Tracheal Intubation*, Grune and Stratton 1983; with permission.)

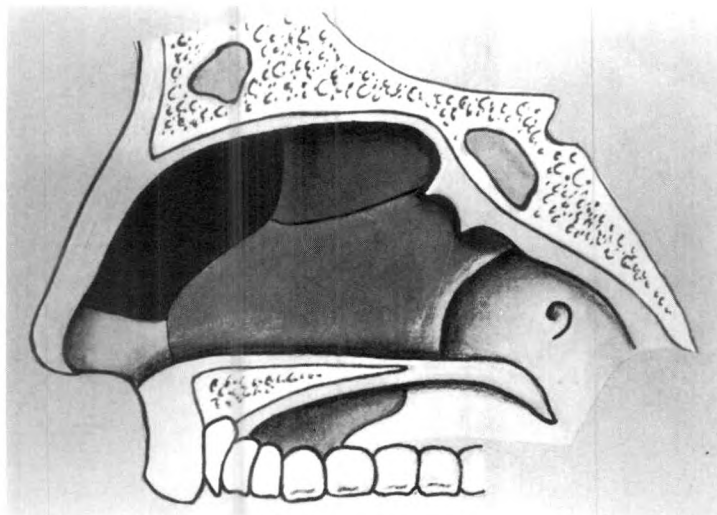


Figure 2. Sensory distribution of the nasal septum. (From Roberts JT: Fundamentals of Tracheal Intubation, Grune and Stratton 1983; with permission.)

and Han's article, may be facilitated by this maneuver. Otolaryngologists commonly examine the larynx with the patient in the sitting position. A Macintosh laryngoscope blade may also be used to lift the tongue from the posterior pharyngeal wall to facilitate fiberoptic intubation. In the last article in this issue, a new teaching laryngoscope useful for this purpose is described.

Sensory innervation of the tongue by the lingual, glossopharyngeal, and vagus nerves is illustrated in Figure 3.

PHARYNX

The palatine, nasopalatine, and glossopharyngeal nerves supply sensation to the nasopharynx while the glossopharyngeal nerves supply the oropharynx (Figure 4). Sensation to the base of the tongue, vallecula, epiglottis, aryepiglottic folds and mucosa is supplied by the superior laryngeal nerves.

When the vocal cords appear at an angle in the field of view, the tip of the fiberscope is approaching the laryngeal opening postero-laterally. The laryngoscopist should bend the tip down as he approaches the cords, then rotate the axis of the fiberscope either clockwise or counter-clockwise depending on whether the vocal slit is angled clockwise or counter-clockwise.

Turbinates are occasionally viewed during an oral approach with the fiberscope when the fiberscope tip is inadvertently pointed superiorly. The problem is solved by reversing the direction of bend at the tip of the fiberscope (i.e., bend the tip inferiorly to direct it toward the larynx).

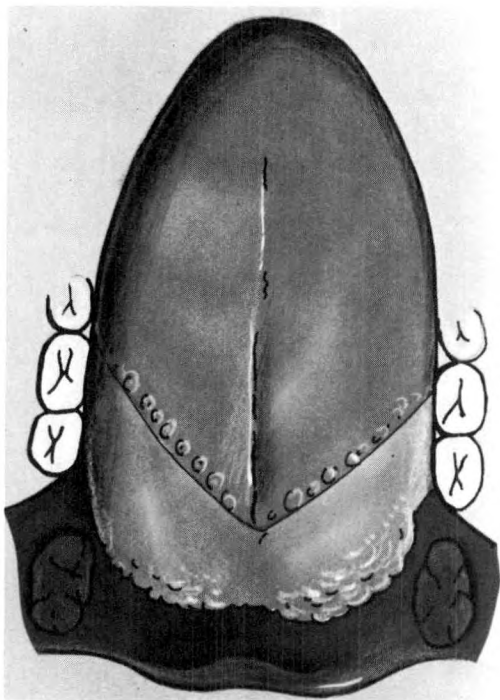


Figure 3. Sensory innervation of the tongue. (From Roberts JT: Fundamentals of Tracheal Intubation, Grune and Stratton 1983; with permission.)

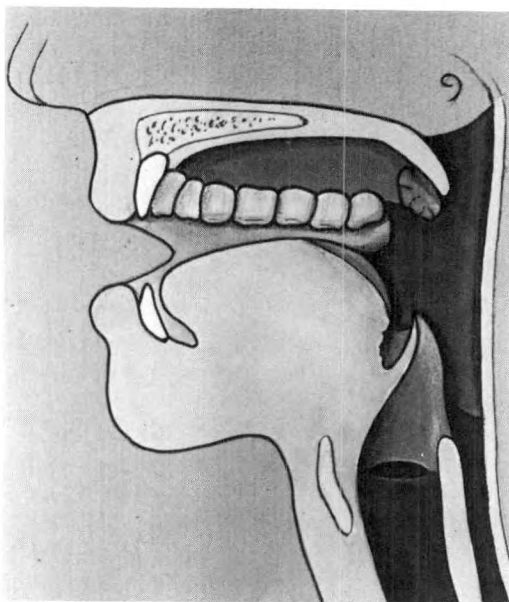


Figure 4. Sensory distribution to the pharynx. (From Roberts JT: Fundamentals of Tracheal Intubation, Grune and Stratton 1983; with permission.)

LARYNX

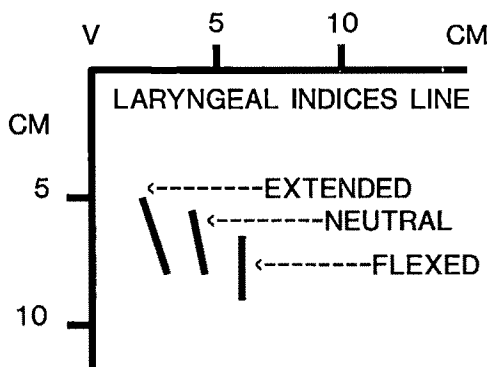
The epiglottis is another common anatomic barrier to the fiberscope. In its role as protector of the airway, the epiglottis normally lies against the posterior pharyngeal wall. Gravity accentuates the apposition when the patient is supine. Placing the patient in the sitting position may improve laryngoscopy. When this is not practical, several maneuvers are helpful. As previously reported, placing the patient in the sniffing position improves laryngeal access with a Macintosh laryngoscope blade but hinders the flexible fiberoptic approach. Extending the cervical spine and extending the atlanto-occipital joint both increase the anterior tilt of the larynx (Figures 5 and 6) and lift the epiglottis, opening a channel to advance the fiberscope (see Figures 7 and 8).

The shape of the epiglottis may affect advancement of the fiberscope. Figure 7 also illustrates a horseshoe-shaped epiglottis that narrows the entrance to the larynx. In this case, the tip of the fiberscope may be forced laterally. Such an epiglottis may also hinder intubation during direct laryngoscopy with a Macintosh laryngoscope.

The epiglottis is innervated by the sensory branch of the superior laryngeal nerve (a branch of the vagus), as illustrated in Figure 4. The piriform recess, which is commonly entered when the fiberscope is advanced off the midline, is also innervated by the superior laryngeal nerve (Figure 9). The laryngoscopist should start looking through the fiberscope when the tip is inserted at least 8 cm past the teeth. If the laryngoscopist begins looking through the fiberscope when only 2 cm of the fiberscope are past the teeth, then one frequently advances the fiberscope into one or the other piriform recesses. An airway designed for fiberoptics helps keep the scope midline (when the airway lies in the midline). Occasionally, the airway is not precisely directed to the midline, in which case it guides the tip of the fiberscope lateral to the laryngeal opening. When the laryngoscopist is blinded, the author recommends withdrawing the fiberscope until a landmark is identified. This may be the teeth—at least you know where you are. You may then reinsert the fiberscope following the midline.

The entrance to the esophagus lies posterior to the larynx and the piriform recesses. It is easily entered by even the skilled laryngoscopist.

Figure 5. Extension of cervical spine. Sloped line represents the anterior surface of the thyroid cartilage. (From Roberts JT, Ali HH, Shorten GD, Gorbach MS: Why flexing the cervical spine facilitates direct laryngoscopy with a Macintosh laryngoscope but hinders laryngoscopy with a flexible fiberoptic laryngoscope. Presented at the 1990 meeting of the American Society of Anesthesiologists in Las Vegas.



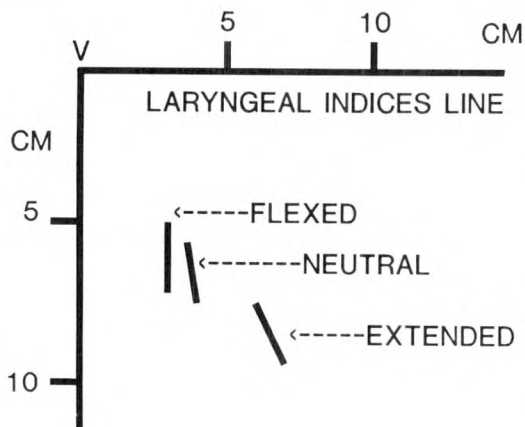


Figure 6. Atlanto-occipital extension. Sloping line represents the anterior surface of the thyroid cartilage. (From Roberts JT, Ali HH, Shorten CD, Gorbach MS: Why flexing the cervical spine facilitates direct laryngoscopy with a Macintosh laryngoscope but hinders laryngoscopy with a flexible fiberoptic laryngoscope. Presented at the 1990 meeting of the American Society of Anesthesiologists in Las Vegas.

Insufflation of oxygen through the channel of the fiberscope may enter the esophagus and hence the stomach; therefore, do not insufflate oxygen unless you can assure yourself that you are not in the esophagus.

TRACHEA

On many occasions, the laryngoscopist is blinded immediately after passing the tip of the fiberscope through the vocal cords. Figure 10 illustrates the angle of the trachea relative to the angle of approach to the vocal cords. Once the tip of the fiberscope is just past the vocal cords, it should be bent to lie in the long axis of the trachea. This means that the tip should be bent downward if the laryngoscopist stands at the head of the patient and upward if he stands by the patient's side or facing the patient.



Figure 7. Epiglottis in apposition to posterior pharyngeal wall during sniffing position. (From Roberts JT, Ali HH, Shorten CD, Gorbach MS: Why flexing the cervical spine facilitates direct laryngoscopy with a Macintosh laryngoscope but hinders laryngoscopy with a flexible fiberoptic laryngoscope. Presented at the 1990 meeting of the American Society of Anesthesiologists in Las Vegas.

Figure 8. Epiglottis separated from the posterior pharyngeal wall by cervical and atlanto-occipital extension. (From Roberts JT, Ali HH, Shorten GD, Gorback MS: Why flexing the cervical spine facilitates laryngoscopy with a Macintosh laryngoscope but hinders laryngoscopy with a flexible fiberoptic laryngoscope. Presented at the 1990 meeting of the American Society of Anesthesiologists in Las Vegas.

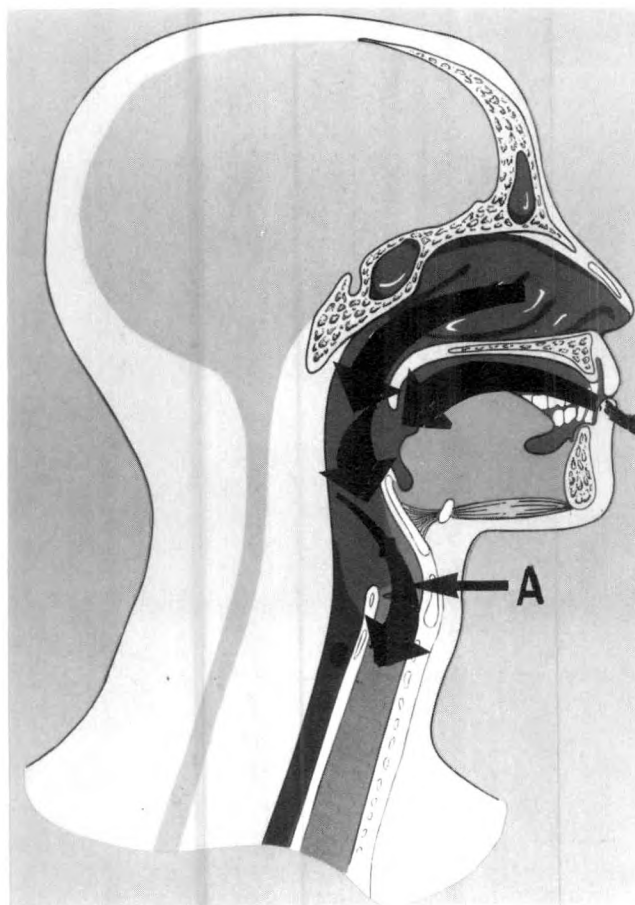
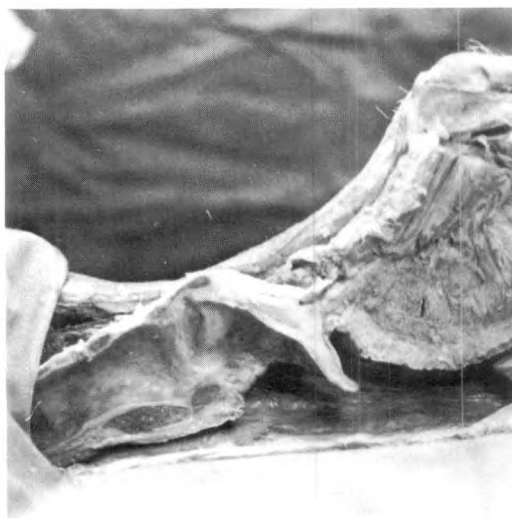


Figure 9. Sagittal section illustrating the change in direction (A) of the trachea relative to the oropharynx.

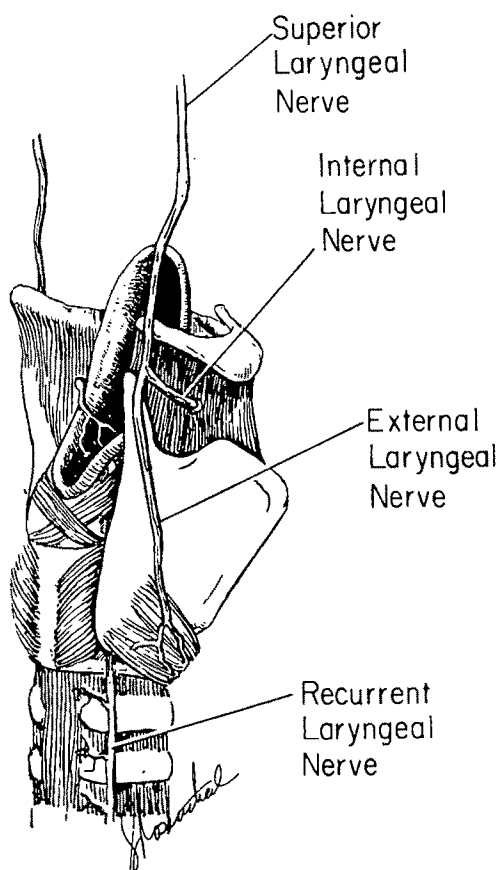


Figure 10. Superior laryngeal nerves innervating the larynx. (From Roberts JT: Clinical Management of the Airway, WB Saunders, in press.)

Sensory innervation of the trachea is supplied by the inferior (recurrent) laryngeal nerve. When these nerves are bilaterally blocked or injured, and the superior laryngeal nerves left intact and unopposed, the vocal cords are tightened because of the unopposed activity of the cricothyroideus muscles. Extubation under these circumstances leads to complete airway obstruction.

While not being fixed anatomical structures, secretions and blood in the trachea may also hinder fiberoptic laryngoscopy.

ANATOMIC LANDMARKS FOR SUPERIOR LARYNGEAL NERVE BLOCKS

Awake fiberoptic intubation may be facilitated by blocking the superior laryngeal nerves. There are three common approaches to these nerves: the lateral percutaneous, the midline percutaneous, and the intraoral.

The lateral percutaneous approach may be performed as follows: palpate the superior horn of the thyroid cartilage. Insert the needle tip of a syringe filled with 1% lidocaine percutaneously through a sterile field

until it touches the superior horn. Slide the tip anteriorly off the superior horn to a depth of 1 cm. After aspirating unsuccessfully (i.e., no air or blood), inject 2 ml as the needle is withdrawn. Repeat the injection on the contralateral side.

With a midline percutaneous approach, the needle is inserted at the thyroid notch, then along the medial thyroid lamina surface on each side. The spread of anesthetic will affect the sensory but not the motor branches of the superior laryngeal nerves.

The intraoral approach to the superior laryngeal nerves involves injection of a local anesthetic or placement of the local anesthetic topically in the piriform recesses.

PATIENT POSITIONING FOR FIBEROPTIC LARYNGOSCOPY

Positioning the patient for direct laryngoscopy introduces several obstacles for flexible fiberoptic laryngoscopy. The classic position for direct laryngoscopy is the "sniffing position," where the patient's head is placed on several blankets, which flexes the cervical spine, and the atlanto-occipital joint is extended. This usually places the epiglottis against the posterior pharyngeal wall (see Fig. 7). In this position, it is difficult to maneuver the tip of the fiberscope under the epiglottis, and placing the fiberscope tip directly against the mucosa smears secretions on the distal coherent lens, blinding the operator.

To optimize the patient's position for flexible fiberoptic laryngoscopy, remove the blanket from under the patient's head, and extend the atlanto-occipital joint by lifting the mandible anteriorly. This lifts the epiglottis from the posterior pharyngeal wall (see Fig. 8).

Normally, the operating room table is elevated to make direct laryngoscopy comfortable by placing the observer's head close to the patient's mouth. Elevation of the table tends to place a torque on the fiberoptic bundle, which may cause disorientation. Therefore, the operating room table should be lowered, thus keeping the fiberbundle extended to maintain orientation during insertion of the fiberscope.

SUGGESTED READING

1. Roberts JT: Fundamentals of Tracheal Intubation, New York: Grune and Stratton, 1983.
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Address reprint requests to

James T. Roberts, MD
Department of Anesthesia
Massachusetts General Hospital
32 Fruit St.
Boston, MA 02114

The Prediction of Difficult Intubation

George D. Shorten, FFARCS(I), FCAnaes,*
and James T. Roberts, MD†

"... The idea seems to have developed that luck is the chief factor in the achievement of a good view of the vocal cords."²

The clinical problems that most warrant attention are those that are potentially life threatening, that occur frequently and that are amenable to treatment or prevention. One retrospective study on general surgical patients calculated a 'failed intubation' incidence of 1:2230.¹⁷ More than a century of anesthetic literature bears witness to the danger of rendering a patient apneic and thereafter failing to secure the airway in order to control ventilation. One study of closed claims related to anesthetic mishaps estimated that 4% (22 of 624) of the analyzed cases related to difficult intubation.¹ However, of these 22 patients, 9 died and 4 suffered brain damage. The wide range of ingenious devices available to facilitate intubation indicates the anesthesiologists' awareness of the problem. Many attempts have been made to identify the patient characteristics most likely to make direct laryngoscopy or intubation difficult. (In this chapter we will refer specifically to either laryngoscopy or to intubation, in order to avoid the assumption that an inadequate view of the larynx necessarily makes intubation difficult).

Any study designed to investigate this question must overcome the problems of standardization of the compared groups, quantitation of the parameters studied and the large numbers of patients required for a prospective trial. Ideally, control and study groups in a clinical trial are well matched for all factors except those to be studied. If a particular intubation is deemed difficult, it is necessary for the purposes of comparison to know many factors other than the anatomical features of the patient, e.g., the experience of the intubator, the laryngoscope and blade used, the position of the patient's head and neck, whether profound muscle relaxation was achieved and whether a trained assistant was present. Horton et al have proposed a standard intubating position based on the degree of lower

*Instructor in Anesthesia, Harvard Medical School; and Clinical/Research Fellow, Massachusetts General Hospital, Boston, Massachusetts

†Professor, Department of Anesthesia, Massachusetts General Hospital, Boston, Massachusetts

neck flexion and extension of the plane of the face relative to the horizontal which would serve as a research standard.⁸

The relevant anatomical features are not easily measured. How high is a "high arched palate"? How anterior is an "anterior larynx" and anterior to what? Structural images examined radiologically may be accurately measured and the relevance of such measurements has been clearly demonstrated. However, the routine use of X-rays for this reason as part of the preanesthetic assessment is impractical. Mallampati had suggested that oropharyngeal appearance (of the sitting patient with the mouth wide open and tongue protruded maximally) be examined and classified.¹² In a prospective trial he clearly demonstrated that such appearances are predictive of the ease of laryngoscopy. While its limitations have been pointed out (in particular, observer variability, unsatisfactory results and failure to take cervical mobility into account, this simple test may easily be performed at the bedside and appears to have gained widespread acceptance.^{6, 7, 20} Recently, we have described a device, the laryngeal indices caliper, designed to measure a number of upper airway parameters relative to a predefined standard (the laryngeal indices line, joining the upper incisor to the external auditory canal in a lateral view of the subject).¹⁵ A second device, the bubble inclinometer, may be used to measure the degree of anterior tilt of the thyroid cartilage relative to the horizontal.¹⁶ Both of these instruments are easy to use, involve no patient discomfort and the measurements obtained are reproducible and relevant to the prediction of difficult laryngoscopy. The range of atlanto-occipital extension may be accurately measured using a goniometer (a device comprising a pair of articulated rulers calibrated to read the angle between them.) Other measurements, e.g., maximal incisor separation and chin to suprahyoid notch distance may simply be made using a ruler.

If one of each 2000 general surgical patients prove difficult to intubate, perhaps a single proposed factor may contribute to one fifth of such cases. Thus, 10,000 patients requiring intubation must be studied to encounter one in whom the proposed factor is responsible. To study such a factor prospectively, perhaps 10 such cases are required to achieve statistical significance. Therefore, a conclusion may be drawn only when 100,000 patients have been studied using a carefully standardized intubation technique. While the actual figures mentioned above represent guess work, the numerical difficulties to be overcome may be appreciated.

The experienced anesthetist has long been alert to the difficulties to be encountered when attempting to intubate patients with certain characteristics. In 1956, Cass et al described six anatomical features that "cause" difficult intubation. While five of these features had previously been recognized, Cass supported his conclusion with a series of six brief case reports. Brechner, in 1968, emphasized the importance of the mobility of the cervical vertebrae in proper positioning of the head and neck for intubation.⁴ Measurements made using lateral, postero-anterior and submental-vertical radiographs by White and Kander suggested that the reduction in the distance between the occiput and the spinous process of C1 and to a lesser extent the C1-2 interspinous gap were important factors.¹⁸ They concluded that the most significant determinant of ease of laryngos-

copy is the posterior depth of the mandible, a finding that has not been confirmed in other studies. Bellhouse and Doré analyzed measurements made using lateral radiographs and concluded that reduced atlanto-occipital extension, reduced mandibular space and increased antero-posterior thickness of the tongue were the three most reliable factors in distinguishing between difficult and straight forward intubation.³ More importantly, they described a method of assessing these variables clinically. They recommended a combination of Mallampati-style inspection of the oropharynx with a grading of reduction of head extension (none, one-third, two-thirds complete) and estimation of chin recession. Nichol and Zuck explained the importance of a small atlanto-occipital gap by pointing out that in such cases, attempts to extend the head result in anterior bowing of the cervical spine thus displacing the larynx forward, out of the laryngoscopist's line of vision.¹⁴

Recent work of ours identifies one previously undocumented variable which influences ease of laryngoscopy namely the degree of anterior "tilt" of the larynx.^{15, 16} This concept may be best understood if one envisions that when the longitudinal axis of the larynx forms a large angle with the line of vision achievable with a laryngoscope blade, then direct laryngoscopy is more difficult. We measured a number of upper airway variables, using the Laryngeal Indices Caliper for association with laryngoscopic appearance. Of these, only laryngeal tilt showed a strong positive association. Subsequently, we demonstrated that laryngeal tilt, relative to the horizontal and measured with the bubble inclinometer, was equally predictive of laryngoscopic appearance.

From published work on this subject, three principles have clearly emerged. Firstly, to gain widespread support, any predictive test must be amenable to simple painless application at the bedside. Secondly, no single factor is predictive of difficult intubation or laryngoscopy. Thirdly, the predictive value of any factor depends on the accuracy with which it can be measured. Wilson et al combined five critically assessable risk factors to create a predictive index.¹⁹

The anaesthetic literature contains a long and growing list of clinical conditions said to be associated with difficult intubation. These, for the most part, pose less a problem of prediction than of awareness that an airway problem may exist. If this possibility is considered, one need not resort to clinical tests or radiographic measurements to detect the gross anatomical abnormalities present. While some such conditions are commonly encountered in anesthetic practice (e.g., following trauma, burns, or radiation), others are rare. Thus, a detailed review such as that by Jones and Pelton⁹ (supplemented by that of McIntyre¹⁰) seems useful as a course of reference.

So integral a part of modern general anesthesia is endotracheal intubation and so great are the risks of a failed attempt that assessment of the patient's upper airway must comprise a crucial part of any preanaesthetic visit. This assessment has two objectives: firstly to identify those patients in whom intubation is likely to be difficult and secondly, with the anatomical basis for such a prediction in mind, to decide how the patient's airway may be safely secured.

McIntyre has suggested a systematic approach to how these objectives might be achieved.¹⁰ He emphasizes the importance of taking a complete history at the pre-anesthetic visit "as diseases or syndromes primarily affecting other parts of the body may have a component that makes intubation difficult." His comprehensive plan for clinical examination comprises six steps: (1) Viewing the patient from the lateral and anterolateral position; (2) Viewing and palpating the neck anteriorly and laterally; (3) Extending the neck maximally; (4) Flexing the neck maximally; (5) Examining the mouth opening, teeth and oral cavity; (6) Determining the patency of the nostrils.

We recommend an approach to examination which differs in emphasis from that of McIntyre. We concentrate on the line of vision (LOV) which the laryngoscopist hopes to achieve and in so doing assess all those factors shown to influence ease of laryngoscopy. The LOV is potentially created when the axes of buccal cavity, oropharynx and larynx are brought into line. Thus lower neck flexion and atlanto-occipital extension are assessed by placing the awake supine patient in the standard intubating position. By asking the patient to sit, open his mouth and protrude his tongue maximally (as suggested by Mallampati) potential obstacles to the proximal line of vision may be assessed (i.e., limited mouth opening, prominent incisors, macroglossia, oropharyngeal structures).

The integrity of the distal line of vision is primarily dependent on laryngeal position (the "high, anterior larynx") or tilt. These may simply be assessed by measuring the distance from chin to thyroid prominence (a distance less than 6 cm suggests laryngoscopy will be difficult) and using a bubble inclinometer, respectively.¹⁶

These four steps may easily be performed in less than 1 minute and will predict most difficult intubations. The posterior mandibular depth has deliberately been ignored since its significance is doubtful.¹⁹ Other factors such as obesity and sternal prominence will be obvious on general inspection of the patient. The use of an objective grading system or actual measurement reduces the extent to which an assessment is based on the observer's experience.

The information thus obtained will be useful in selecting the safest intubation technique in a specific patient (the second objective of the preanesthetic assessment). While elective tracheostomy using local anesthesia remains an option, awake fiberoptic intubation will overcome many of the anatomical obstacles encountered. However, neither a fiberoptic laryngoscope nor personnel trained in its use are available in every center. Furthermore, particularly in the presence of inadequate topicalization, its use may precipitate laryngospasm. McIntyre has cleverly matched laryngoscopic characteristics with some of the commonly encountered problems.¹¹ For instance, the protruding sternal region that makes introduction of the blade into the mouth impossible is best managed by increasing the angle between the blade and the handle or by offsetting the blade from the handle or by shortening the length of the laryngoscope handle. For a reduced intraoral cavity, he recommends a blade with a substantial flange such as the Wisconsin, Flagg or Guedel laryngoscopes. A straight blade with a distal curve or beak directed anteriorly may be useful in obtaining a view of the anterior larynx.

In summary, we emphasize the importance of attempting to anticipate specific cases of difficult intubation. Some of the obstacles to be overcome in any scientific appraisal of the problem are pointed out. Those factors proved to be useful predictors of difficult intubation are enumerated and discussed. Alternative techniques for airway assessment suitable for routine clinical use during the preanesthetic visit, are described. Finally, we suggest that the intubation plan is best chosen with the aid of such an assessment. To paraphrase George Orwell, all intubations are potentially difficult, but some are more difficult than others.

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Address reprint requests to

George D. Shorten, FFARCS
Department of Anesthesiology
Massachusetts General Hospital
32 Fruit St.
Boston, MA 02114

Preparation of the Patient for Awake Fiberoptic Intubation

Allan P. Reed, MD,* and Don G. Han, MD†

Preparations for this procedure begin as soon as the decision has been made to use the technique. Awake fiberoptic intubation (FOI) represents a special service to the patient, but it can often result in some discomfort, causing the patient to recall it as an unpleasant experience. For this reason, both the patient and physician benefit from a frank discussion of the specific indication for awake FOI as well as the potential complications it entails. Each patient must understand the unusual circumstances requiring awake FOI and be convinced of the increased safety margin offered by its use. Patients at increased risk for airway obstruction, hypoxemia, upper airway trauma, cervical spinal cord damage, and/or dental damage usually understand the need for awake intubation and agree to it,¹⁴ albeit with appropriate reservations. The common indications for awake FOI are listed in Table 1.

PREMEDICATION

Patients of the 1990s are well acquainted with medical disasters of all kinds. Such knowledge can conjure up fears, some of which are valid and some of which are not. As patients approach the operating room, anxiety can be transformed into terror. Premedication represents an attempt to allay the fear experienced prior to surgery, but despite the patient's outward calm, it may do little to prevent extreme emotional distress. The goal is to achieve anxiolysis.²⁷ Unquestionably, establishment of a good doctor-patient relationship is the best way to prevent preoperative terrors.¹⁰ Patients who have faith in their physician's expertise and caring personality tend to be more relaxed. Consequently, the preoperative interview offers an opportunity, not only to comprehend the patient's physiologic requirements, but also to establish the personal chemistry that will flourish into a strong

From The Mount Sinai School of Medicine, New York, New York

*Assistant Professor of Anesthesiology

†Resident in Anesthesiology

Table 1. Indications For Awake Fiberoptic Intubation

Trauma of the:
Upper Airway
Hematomas
Lacerations
Cervical Spine
Instability
Face
Small mouth opening
Hematomas
Lacerations
Congenital Airway Abnormalities
History of Difficult Intubation
Trismus Due to Mechanical Problem: Temporomandibular Joint Ankylosis
Unstable Cervical Vertebrae
Anticipated Difficult Intubation
Micrognathia
Short muscular or obese neck
Decreased temporomandibular joint range of motion
Prominent "buck" teeth

doctor-patient relationship. It is important to conduct the interview in a sincere and unhurried fashion. Although the anesthesiologist has seen numerous similar circumstances, the patient has not. Matters that are routine to the physician are unique and overwhelming to the average patient. The investment of time into a professional relationship pays premiums in patient acceptance and cooperation later on.²²

While the psychologic preparation of the patient relies on personal interactions, the pharmacologic preparation requires judicious use of medications. Although innumerable combinations of drugs can be successfully employed, there exists one inviolate concept, DRY THE AIRWAY! Copious secretions in the airway create two problems. Secretions further obscure an already limited view through the fiberscope. Although various suctioning maneuvers usually restore the view, elimination or reduction of this impediment allows for easier and faster intubation. Secondly, awake FOI requires use of topical local anesthetics. In order for these agents to work effectively, they must actually contact the mucosa. An intervening layer of secretions prevents local anesthetics from reaching the intended areas, resulting in failed sensory blockade. Moreover, copious secretions could wash local anesthetics away from a particular site, thereby severely limiting its duration of action. Topical local anesthetics applied to the airway are of no benefit when antisialogogue premedication is eliminated.²⁰

The antisialogogues used in current practice are atropine, glycopyrrolate, and scopolamine. Their clinically relevant profiles are outlined in Table 2. These agents prevent further liberation of secretions, but they do not eliminate the secretions that have already accumulated. Consequently, even a rapid-acting drug such as atropine must be administered sufficiently far in advance, in order to block further collections and in order to allow for elimination of previous collections. Antisialogogues are best administered as premedication and should be received approximately 1 and one half hours prior to application of topical local anesthetics.¹¹ One of the most

Table 2. Antisialagogues Employed in Common Clinical Practice

	ANTISIALOGUE DOSE IN MG	ONSET	DURATION	SIDE EFFECTS
Atropine	0.4–0.8 IV, IM, SQ, PO	IV = rapid IM, SQ, PO = 1–2 hrs	IM, SQ, PO = 4 hr	Tachyarrhythmias, PVCs Urinary retention Decreases GI motility Hyperthermia Delirium
Glycopyrrolate	0.1–0.2 IV, IM, SQ 1–2 PO	IV = 1–4 min IM, SQ = 20– 40 min PO = 1 hr	IV = 2–4 hr IM, SQ = 4–6 hrs PO = 6 hrs	Tachyarrhythmias, PVCs Urinary retention Decreases GI motility
Scopolamine	0.3–0.6 IV, IM, SQ	IV = 1 min		Delirium or excitement Tachyarrhythmias Hyperthermia Amnesia Sedation

important side effects of antisialagogue use is dysrhythmias. Because dysrhythmias are more likely to occur following intravenous administration, it is advisable to give them intramuscularly, subcutaneously, or by mouth. Although scopolamine offers the additional benefits of added amnesia and sedation, its use is limited by an important side effect, delirium. Additional premedicants usually include benzodiazepines, butyrophenones, and/or narcotics. Patients with significant airway compromise oftentimes require conscious muscle tone to maintain airway patency. Sedating such patients in the nursing unit may seriously jeopardize their ability to oxygenate and ventilate. Airway collapse may occur when they are unmonitored and alone in their rooms or in an elevator while attended by unskilled paramedical personnel. Under such conditions, institution of prompt, life-saving treatment is unlikely. Consequently, those patients with such severe airway disease should receive only atropine or glycopyrrolate premedication. Additional medications can be administered judiciously under close supervision in the operating room.

SEDATION

Upon arrival in the operating room, venous access and baseline monitoring are established. Monitoring usually includes measurement of blood pressure, pulse and respiratory rate; as well as observation of cardiac rhythm on an ECG display and oxygen saturation on a pulse oximeter. Procedures that require patient cooperation, such as gargling with 4% lidocaine, are performed prior to administration of intravenous sedatives. The partially sedated patient may be unable to follow commands to gargle and expectorate. Even worse, the sedated patient might aspirate. The primary goals for sedation during awake FOI are maintenance of sponta-

neous respiration, adequate oxygenation, and sufficient ventilation. The patient's ability to inspire deeply on command facilitates ventilation and oxygenation. Deep breaths also help to align the vocal cords, larynx, and fiberscope. Secondary goals include amnesia and the ability to cooperate with instructions to take deep breaths. Amnesia of potentially uncomfortable procedures is desirable for the patient's psychologic outlook towards repeat awake FOIs and other medical care. Lingering negative recall of previous medically related experiences can create sufficient anxiety over upcoming events, to dissuade patients from accepting further medical care. Induction of amnesia under these circumstances is a way to prevent overwhelming anxiety from entering into further decision-making processes. It is not an attempt to hide information from the patient.

Although numerous combinations of medications can achieve these goals, it is the narcotics, benzodiazepines, and butyrophenones that are most commonly employed. Ketamine's tendency to produce secretions and postoperative hallucinations relegates it to the "infrequently used" category. The relatively rapid onset of sedation and anterograde amnesia make benzodiazepines a popular choice for awake intubations.^{25, 34} The commonly used benzodiazepines are midazolam, diazepam, and lorazepam. Although lorazepam provides the most profound sedating and amnestic properties, it is difficult to use because of its relatively slow onset time, 5–20 minutes (Table 3). Midazolam and diazepam, with onset times of 3 minutes or less, are both easier to use than lorazepam. Regardless of the specific drug selected, small incremental doses are administered until achieving a sedated, but cooperative state. The interval between successive doses should be at least equivalent to the drug's maximal onset time. Otherwise, the patient soon becomes oversedated, uncooperative, and apneic. Midazolam is supplied as a water-soluble compound, but diazepam is prepared in a propylene glycol¹⁵ and benzoic acid formulation that frequently produces a burning sensation on injection and causes irritation of endothelial linings, which predisposes to thrombosis. The burning sensation can be prevented by mixing lidocaine with diazepam before injection.

Occasionally, a butyrophenone is substituted for one of the benzodiazepines. Droperidol is the butyrophenone most commonly employed. Droperidol possesses unique properties. It allows the outwardly calm and seemingly comfortable patient to undergo otherwise painful procedures without recoiling from noxious stimuli. Contrary to some reports, however, droperidol is not a good amnestic.³⁵ Patients exposed to painful stimuli, while receiving droperidol, recall the events clearly. Its onset of peak action may require 20 minutes, predisposing to cases of overdose, whenever incremental administration proceeds too rapidly. Side effects include dysphoria, extrapyramidal symptoms, and hypotension. The onset of extrapyramidal effects may be delayed for 6–12 hours, thereby manifesting postoperatively.²⁹ Another beneficial property of droperidol is that of antiemesis.

Narcotics are often added to the sedating regimen for their analgesic and euphoric effects. An additional benefit of narcotics is the capability of depressing laryngeal reflexes.¹² Although any of the narcotics can theoretically be selected for this purpose, morphine and fentanyl have been used most extensively. The onset of action of intravenous morphine is approxi-

Table 3. Characteristics of Sedatives Frequently Used For Awake Fiberoptic Intubation

SEDATIVES	PHARMACOLOGIC ACTIONS	DOSE*	ONSET TIME*	DURATION*	SIDE EFFECTS
Benzodiazepines:					
	Sedation				
	Anterograde amnesia				
	Antiepileptic				
Midazolam		IV, IM = 5–7 mg (0.075 mg/kg)	IV = 1–3 min ³⁴ IM = 15–30 min	IV, IM = 2 hrs	Respiratory impairment in high doses
Diazepam		IV = 2–7 mg (0.03–0.1 mg/kg) IM = Not recommended PO = 3–11 mg (0.05–0.15 mg/kg)	IV = <3 min IM = 15–30 min PO = 30–60 min	IV = min-hrs ^{15, 25}	Respiratory impairment in high doses Thrombophlebitis IV and IM injections painful
Lorazepam		IV, IM, PO = 1–4 mg	IV = 5–20 min IM = 30–120 min PO = 60–120 min	IV = 4–6 hrs IM, PO = 8 hr	Respiratory impairment in high doses
Butyrophenones:					
	Sedation				
	Antiemetic ²⁴				
	Indifference				
Droperidol		IV, IM = 0.625–10.0 mg	IV, IM = 5–20 min	IV, IM = 6–12 hrs ⁹	Dysphoria ²¹ Extrapyramidal symptoms ³⁰ Mild alpha-adrenergic antagonist Prolongs emergence from anesthesia
Narcotics:					
	Analgesia				
	Sedation				
Morphine		IV, IM, SQ = 2–10 mg	IV = 5–10 min IM = 30–60 min SQ = 30–90 min	1–6 hrs	Respiratory depression Bronchospasm Chest wall rigidity Bradycardia Vomiting Hypotension Biliary spasm Similar to morphine
Fentanyl		IV, IM = 50–100 µg	IV = 2 min IM = 10–15 min	IV, IM = 30–45 min	Bronchospasm, hypotension and biliary spasm are less common

*Dosages and times quoted above represent broad generalities. They may be highly variable for any one patient. Consequently, slow careful titration is required in each case.

mately 10 minutes. Fentanyl's onset of action is only 2 minutes. In order to hasten an already time-consuming procedure, agents with shorter onset times are more desirable. Narcotics generally produce respiratory depression and oftentimes result in bradycardia.

Combinations of droperidol and narcotics represent neuroleptanalgesia, which provides moderate degrees of analgesia, sedation, and cardiovascular stability. It does not, however, ensure protection from recall, hypoxia, hypercarbia, tachycardia, or hypertension. Achievement of the desired goals requires multiple incremental doses, allowing for the clinical effect of each dose prior to administering more. A combined preparation of fentanyl and droperidol (Innovar, Janssen Pharmaceutica, Inc., Piscataway, NJ) is commercially available. Its exclusive use is ill-advised. Multiple repeat doses of Innovar provide excessive and cumulative amounts of droperidol which may last for 6–12 hours or more.⁹ Fentanyl's actions usually last only 1–2 hours, depending upon multiple factors. Consequently, postoperative patients tend to experience prolonged emergence, dysphoria, and pain following large doses of droperidol. Once attaining an appropriate dose of droperidol, subsequent episodes of pain are best treated solely with narcotics.

When administered individually, neither narcotics nor benzodiazepines produce significant cardiovascular impairment. However, combinations of diazepam and high doses of fentanyl have been shown to produce decreases in myocardial contractility, systemic vascular resistance, heart rate, cardiac output, and hypotension.^{31, 2, 32} Even at moderate and low doses of midazolam and fentanyl, a synergism exists which potentiates the effects of both drugs.³ Analgesia for awake FOI is provided with local anesthetics. Consequently, it is unlikely that sufficiently high doses of fentanyl will be required to interact adversely with the cardiovascular system, even in combination with diazepam.

ANALGESIA OF THE AIRWAY

Awake FOI requires instrumentation of anatomic structures that usually result in violent withdrawal, explosive vomiting, or vigorous coughing. Each one of these reactions, by itself, is sufficient to prevent successful FOI. Consequently, a scheme for blocking sensory input from the airway must be devised. To accomplish this task in a logical manner requires an understanding of the sensory innervation to the upper airway.

The upper airway begins simultaneously at both the nose and mouth (Table 4). Sensory innervation of the nose is supplied by the trigeminal nerve (V). Afferent input from the tongue is divided between two nerves. The lingual nerve (V) supplies the anterior tongue and the glossopharyngeal nerve (IX) supplies the posterior tongue. The pharynx receives sensory input from the glossopharyngeal nerve (IX) and the vagus nerve (X). The upper larynx is supplied by the superior laryngeal nerve (X). Both the vocal cords and lower larynx receive afferents from the recurrent laryngeal nerve (X). Lastly, the trachea is supplied by the vagus nerve (X). The superior laryngeal nerve actually divides into an internal and external branch. The

Table 4. Sensory Innervation of Upper Airway Segments

STRUCTURE	INNERVATION
Nose	Trigeminal (V)
Tongue	Anterior-Lingual (V)
	Posterior-Glossopharyngeal (IX)
Pharynx	Glossopharyngeal (IX)
	Vagus (X)
Upper larynx	Superior Laryngeal (X)
Vocal cords	Recurrent Laryngeal (X)
Lower larynx	Recurrent Laryngeal (X)
Trachea	Vagus (X)

internal branch of the superior laryngeal nerve supplies sensory innervation from the inferior aspect of the epiglottis down to (but excluding) the vocal cords. This segment is called the upper larynx. The external branch of the superior laryngeal nerve supplies only motor innervation and does so to only one muscle, the cricothyroid muscle. The recurrent laryngeal nerve carries both sensory and motor fibers. The sensory portion of this nerve is distributed to the vocal cords, lower larynx, and trachea. Its motor contributions go to all the laryngeal muscles except the cricothyroid muscle (Table 5).

Clearly, the sensory innervation of the upper airway is carried by cranial nerves and their branches. Unlike major conduction anesthesia or perivascular anesthesia, upper airway anesthesia cannot be accomplished from any one central needle location. In fact, the cranial nerves that supply the airway are extremely difficult to anesthetize individually.

Numerous safe techniques of upper airway anesthesia exist and will be divided into four major categories. In order of discussion, they are superior laryngeal nerve blocks, topical vasoconstrictors, topical local anesthetics, and transtracheal blocks.

Superior Laryngeal Nerve Block

The superior laryngeal nerve, a branch of the vagus nerve (X), courses inferiorally in the neck. At approximately the level of the hyoid bone, it dives deep to pierce the thyrohyoid membrane that stretches between the hyoid bone and thyroid cartilage. At about this point the superior laryngeal nerve divides to produce an internal and external branch. The internal

Table 5. Innervation of The Larynx

NERVE	FUNCTION
Internal Branch of the Superior Laryngeal (Vagus)	Sensory from the inferior aspect of the epiglottis to (but excluding) the vocal cords (upper larynx)
External Branch of the Superior Laryngeal (Vagus)	Motor to the cricothyroid muscle
Recurrent Laryngeal (Vagus)	Sensory from the vocal cords to lower larynx and trachea
	Motor to all laryngeal muscles except the cricothyroid muscle

branch of the superior laryngeal nerve provides sensory innervation to the upper larynx and the external branch of the superior laryngeal nerve gives off motor fibers to the cricothyroid muscle (Fig. 1, *top*).

The superior laryngeal nerve is blocked at the level of the thyrohyoid membrane. The patient lies supine with the head extended. Labat's initial description of this nerve block used the hyoid bone as the primary landmark.¹ Unfortunately, the hyoid bone is difficult or impossible to feel in many patients. Also, it frequently requires deep palpation, which is uncomfortable for most individuals. Consequently, we prefer to use the thyroid cartilage as the major landmark. The thyroid cartilage is located more superficially and is more readily identifiable.

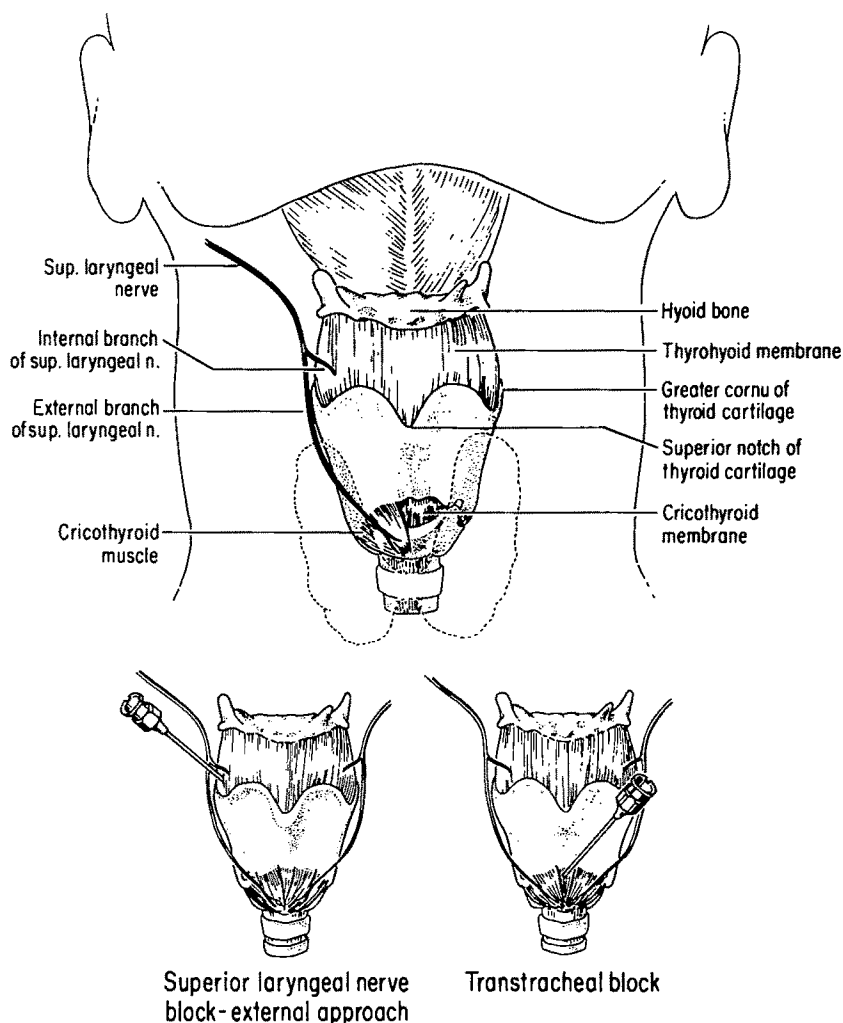


Figure 1. Composite Diagram of Nerve Blocks. Anatomy of the neck (*top*); Needle placement for superior laryngeal nerve block—external approach (*lower left*); Needle placement for transtracheal block (*lower right*).

The most medial and superficial aspect of the thyroid cartilage, the superior notch of the thyroid cartilage, is commonly known as the Adam's apple. This midline structure (Adam's apple) is palpated and the operator's fingers are moved laterally across the neck until the end of the thyroid cartilage is identified. This is called the greater cornu of the thyroid cartilage. Prepare the skin over the greater cornu of the thyroid cartilage with isopropyl alcohol. Displace the thyroid cartilage laterally from the opposite side. Take a 3-ml syringe filled with 2 ml of 2% lidocaine and a 25-gauge needle and place the needle through the skin just above the greater cornu of the thyroid cartilage. Once there is resistance to passage of the needle, it lies at the greater cornu of the thyroid cartilage. "Walk" the needle off the greater cornu, in a superior direction. This places the needle between the greater cornu of the thyroid cartilage and the hyoid bone, the area through which the superior laryngeal nerve courses (Fig. 1, *lower left*). If an aspiration test does not yield blood, inject 2 ml of 2% lidocaine without epinephrine. Repeat this procedure on the opposite side. The superior laryngeal nerve block is performed first, because it has a 5–10 minute onset time.

Alternatively, the superior laryngeal nerve can be blocked from the internal approach. Soak a surgical sponge in 4% lidocaine and grasp the sponge with a Krause forceps. Have the patient open his or her mouth as wide as possible. Place the lidocaine-soaked sponge into the piriform fossa and hold it there for 5 minutes by the clock. This must be performed on both sides. The internal approach requires a minimum of 10 minutes and is only applicable to those patients who can open their mouths sufficiently wide.

Topical Vasoconstrictors

Manipulation of the nose generally risks epistaxis and FOI is no exception. Passage of a fiberscope and endotracheal tube is not only uncomfortable, but predisposes to a significant risk of nasal bleeding. Even oral FOI risks epistaxis if it becomes necessary to suction laryngeal secretions because the nasal approach may be required for passage of a suction catheter. Once epistaxis occurs, visualization through the fiberscope becomes impaired. Consequently, vasoconstriction of the nose should be considered regardless of the FOI route intended.

Vasoconstriction of the nose is generally achieved with either cocaine or phenylephrine. For this purpose, cocaine has traditionally been used in concentrations as low as 4% and has high as 10%. Recent evidence suggests that 10% cocaine is associated with coronary artery vasoconstriction, diminished coronary blood flow, and an increase in myocardial oxygen demand.^{18, 19} Because the potential risk of side effects is related to plasma levels, substitution of 4% cocaine for 10% cocaine should diminish the incidence of untoward reactions. Nevertheless, a small segment of the population is especially susceptible to cocaine toxicity because of impaired ability to hydrolyze the drug. Cocaine is degraded by serum cholinesterase and the breakdown products are excreted in the urine. Quantitative or qualitative cholinesterase problems can impair cocaine metabolism, thereby effectively increasing plasma levels.³³ Although cocaine can be sprayed into

the nose, application by cotton pledgets probably prevents excess absorption by limiting the amount that actually reaches alveoli.⁵ The cocaine-soaked cotton pledget is simply introduced into both nares and then advanced slowly into the nasopharynx. Best results are obtained when pledgets remain in place for 10 minutes.

Phenylephrine represents another popular vasoconstrictor. It can be applied in concentrations ranging from 0.25% to 0.5%.¹⁶ Although generally not commercially available, 0.5% phenylephrine solutions are readily formulated in any hospital. Phenylephrine is frequently supplied as a 1.0% solution. Simply add 1 ml of 1.0% phenylephrine to 1 ml of 4% lidocaine to manufacture the proper concentration of phenylephrine. Soak cotton pledgets in this solution and introduce them into both nares and advance into the nasopharynx just as described for the cocaine solutions.

Alternatively, oxymetazoline can be substituted to help prevent epistaxis. Oxymetazoline is a pure alpha adrenergic agonist that produces vasoconstriction of the nasal mucosa. It is not a controlled substance and therefore does not require the strict record keeping associated with cocaine. Oxymetazoline does not reduce catecholamine reuptake and therefore is devoid of euphoric effects as well as arrhythmogenic properties. Oxymetazoline is more effective than 4% lidocaine with 1:100,000 epinephrine or 10% cocaine for preventing epistaxis.²³ Therefore, oxymetazoline seems to represent a superior topical vasoconstrictor which eliminates the theoretic disadvantages of cocaine use. In actuality, side effects related to cotton pledget application of 4% cocaine to the nose seem to be minimal. The disadvantage of oxymetazoline is its lack of local anesthetic properties. When applied topically for vasoconstriction of the nares, oxymetazoline is used in a 0.05% concentration.

Topical Local Anesthetics

Topical local anesthetics represent a highly versatile group that is potentially applicable to either portions of the airway or the entire airway. Oftentimes, patients are given viscous lidocaine as a mouth wash and gargle preparation in order to anesthetize the anterior tongue. The posterior tongue and pharynx are then anesthetized with 4% lidocaine administered by atomizer. Atomized lidocaine can be introduced deeper into the airway by administering each puff during a deep inspiration. In fact, it is possible to anesthetize the entire airway using atomized 4% lidocaine or a similar agent.

Healthy children, especially those between 6 and 7 years of age, react adversely to local anesthetic spraying of the larynx. Children are prone to severe bradycardia following this maneuver. Although preoperative intramuscular vagolytics do not protect against bradycardia, intravenous atropine or glycopyrrolate successfully block heart rate decreases under such circumstances.²⁶

Alternatively, nebulized 4% lidocaine can also anesthetize the entire airway. Simply place 4 ml of 4% lidocaine into a nebulizer, flow oxygen through the nebulizer, and channel the nebulized lidocaine through an oxygen face mask. Instruct the patient to take deep breaths of the solution flowing through the oxygen mask. Although capable of producing profound

anesthesia of the airway, this technique usually requires 20 minutes or more to properly prepare the patient. The nebulized lidocaine method is effective, but very time consuming.

Topical local anesthetics require use of high concentrations which frequently migrate into alveoli where absorption is rapid.⁴ Consequently, using topical local anesthetics places patients at high risk for local anesthetic toxicity.

The topical anesthetic effects of lidocaine may last up to one hour in duration.⁶ Onset of topical lidocaine requires between 1 and 5 minutes.^{7, 17}

Transtracheal Blocks

Transtracheal blocks are intended to provide anesthesia of the vocal cords and trachea. The technique has enjoyed widespread use and is easily performed.

Allow the patient to lie supine with the head extended. Identify the thyroid cartilage in the midline (Adam's apple) and run a finger inferiorly until a depression and another firm structure are felt. This depression is the cricothyroid groove and the firm substance is the cricoid cartilage. A membrane runs from the cricoid cartilage across the groove to the thyroid cartilage and is called the cricothyroid membrane (Fig. 1, *top*). Identify the cricothyroid groove and prepare the skin overlying it with isopropyl alcohol. Use a 3-cc syringe with 2 ml of 2% lidocaine and a 22-gauge needle. Insert the needle through the skin overlying the cricothyroid membrane and direct it posteriorly until piercing the cricothyroid membrane. At this point, the needle bevel should reside within the trachea (Fig. 1, *lower right*). To confirm its proper location, simply aspirate air through the syringe. Warn the patient to expect vigorous coughing and then rapidly inject the 2 ml of 2% lidocaine. Remove the needle immediately following injection. Coughing helps to spread the local anesthetic along the trachea and up against the inferior aspect of the vocal cords, thereby providing topical anesthesia to all these structures.¹⁴ Significant amounts of local anesthetic also reach the alveoli where it is rapidly absorbed. Successful transtracheal block is probably due to both topical anesthesia and in some part to local systemic absorption. Patients with good myocardial reserves and who are at increased risk for aspiration should not receive transtracheal blockade. Successful transtracheal block prevents coughing and expulsion of aspirated materials.⁸

In the absence of transtracheal blockade, sensory anesthesia of the vocal cords may be inadequate. Consequently, stimulation of the vocal cords by the fiberscope results in their adduction, preventing further passage of the scope. Improved sensory anesthesia of the vocal cords is easily achieved. Position the distal end of the fiberoptic bundle above, but adjacent to, the larynx. With the vocal cords located in the center of the visual field, inject 1–2 ml of 4% lidocaine through the suction port. The local anesthetic will exit the fiberscope and contact the vocal cords, thereby providing improved sensory blockade of the vocal cords. Allow several minutes for the lidocaine to take effect and instruct the patient to inspire deeply. As this is accomplished, the anesthetized vocal cords will abduct, allowing passage of the fiberscope.

The airway maintains a well-developed capability of defending itself

against invasion by foreign bodies. Instrumentation elicits withdrawal, vomiting, coughing, and vocal cord closure, any one of which will prevent FOI. Rigid laryngoscopy predisposes to hypertension and tachycardia, while an indwelling endotracheal tube predisposes to bronchoconstriction.¹³ Barring deep general anesthesia, no amount of sedation will prevent these reactions to airway stimulation. Only profound sensory blockade will provide conditions conducive to awake FOI. Furthermore, awake FOI performed under successful airway anesthesia increases mean arterial pressure and heart rate by only 10 mm Hg and 14 beats/minute on average.²³

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Address reprint requests to

Allan P. Reed, MD
Department of Anesthesiology
Mount Sinai School of Medicine
Box 1010
One Gustave L. Levy Place
New York, NY 10029-6574

Oral and Nasal Fiberoptic Intubation with a Single Lumen Tube

*Vijayalakshmi U. Patil, MD**

Fiberoptic endoscopic intubation appears simple when performed by an experienced endoscopist. Ease with the instrument and the technique can only be achieved through preparation, practice and patience. Initial experience is gained by using the instruments on an intubation model. Later, the technique should be employed in patients with normal airway anatomy who require general anesthesia with an endotracheal tube for elective surgery. Numerous intubation techniques^{1-3, 6, 7, 11, 15, 16, 17} and a variety of mechanical aids are available to facilitate fiberoptic intubation.^{4, 5, 8, 9, 10, 12, 13}

Familiarity with appearance of the different structures in the oropharynx, surrounding the glottic opening, as seen through the fiberoptic endoscope, is essential if intubation is to be successful. Structures viewed through the fiberoptic endoscope are different from direct rigid laryngoscopy. The images and fields of vision are small. Fogging of the lens and distortion of the view by secretions and blood are inevitable. Only after successfully intubating patients with normal anatomy should one attempt to intubate the patients with difficult airways. In emergency situations and in other than operating room (OR) settings, many anesthesiologists attempt fiberoptic laryngoscopy after failed conventional intubation by rigid laryngoscope, which leads to unfavorable conditions such as bleeding, tissue distortion, uncooperative patients, and unhappy surgeons. Initial attempts at fiberoptic laryngoscopy may result in severe frustration and failure. Allow sufficient time to prepare the patient and to perform the endoscopic intubation. Keep the techniques simple, use instruments you are familiar with, and reach for an experienced endoscopist's help when needed.

FIBEROPTIC ENDOSCOPY TECHNIQUES FOR TRACHEAL INTUBATION

One must always check the type of endoscope and the working elements of the scope thoroughly. The light source must be compatible

*Assistant Professor, Department of Anesthesiology, SUNY Health Science Center, Syracuse, New York

with the light cord of the scope. Connect the scope to the light source, and adjust the light intensity knob. Application of an antifog agent to the distal lens is mandatory when the endoscope is used in the patient. The lens should be focused against printed material prior to use. Do not try to focus the lens during the procedure. The view may not be clear for several reasons. Secretions, blood are insufficient antifog agents on the lens are possibilities. The insertion tube is thoroughly lubricated with a water-soluble jelly, starting at the distal end just a few centimeters above the tip and moving proximally to avoid the lens. The endotracheal tube is selected relative to the type and size of the endoscope without compromising the patient's ventilation. The endotracheal tube connector is removed and the tube is cut to appropriate length, since longer tubes over the insertion tube are much more difficult to manipulate. The endotracheal tube is threaded over the well of the lubricated insertion tube. Constant flow of oxygen (2–3 L/min.) through the operating channel or suction port provides a higher inspired oxygen concentration, forces mucus, blood and secretions away from the lens, enhancing better visualization of the structures. Incorporating a three-way stopcock in the fiberscope channel permits alternating suction and oxygen flow (Fig. 1).

Endoscopic intubation is usually performed with the patient in the supine position, and the anesthesiologist standing at the head of the table. When general anesthesia is administered, the endoscopist stands to the left of the assistant, allowing the latter access to the anesthesia machine. Some endoscopist may prefer to face the patient in which case the view of the larynx is inverted. Patients who cannot lie flat may be intubated on the semi-Fowlers position. Local anesthesia is safest for such patients, and the anesthesiologist performs the endoscopy facing the patient. When the procedure is performed under topical and/or sedation, an assistant is

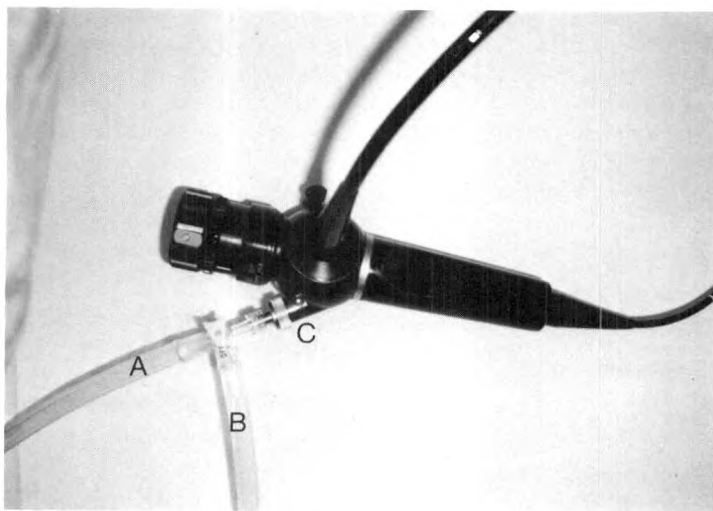


Figure 1. A, A three-way stopcock allows alternate suction and B, oxygen flow through C, the suction port.

desirable. Under general anesthesia, it becomes mandatory for an assistant to monitor the patient and help with the procedure.

The control section of the endoscope is held in one hand, with the thumb on the lever controlling the tip and the index finger on the suction port (Fig. 2). The insertion tube is held straight, with the other hand at an eight to ten centimeter distance from the tip for orotracheal intubation, or twelve to fourteen centimeters for nasotracheal intubation. The lever controlling the tip of the fiberscope is manipulated to ensure that the tip of the endoscope deflects up and down, not sideways. In the adult patient, the insertion tube is introduced into the oropharynx in the midline and maintained in the midline. This is easily achieved by adopting an endoscopic airway, which in addition lifts the base of the tongue and epiglottis from the pharynx, preventing the damage to the scope by an accidental bite by the patient. The endoscope is advanced to the desired length, by looking through the scope to identify the structures.

If the endoscope is in the midline and has been correctly advanced, the vocal cords will come into view as the tip of the scope is deflected upwards (Fig. 3). Further advancement of the scope or slight rotation of the fiberscope may be required in order to visualize the glottis (Fig. 4). A local anesthetic agent can be instilled through the suction port or operating channel onto the larynx if anesthesia is inadequate (Fig. 5). If at this stage one is not able to visualize the larynx, the best advice is to start all over again. It is much faster than trying to manipulate the scope once the anatomical landmarks are lost. Before the reinsertion of the scope, clean the lens, apply the antifog agent as required, holding the insertion tube to the appropriate distance from the tip, and insert the scope into the

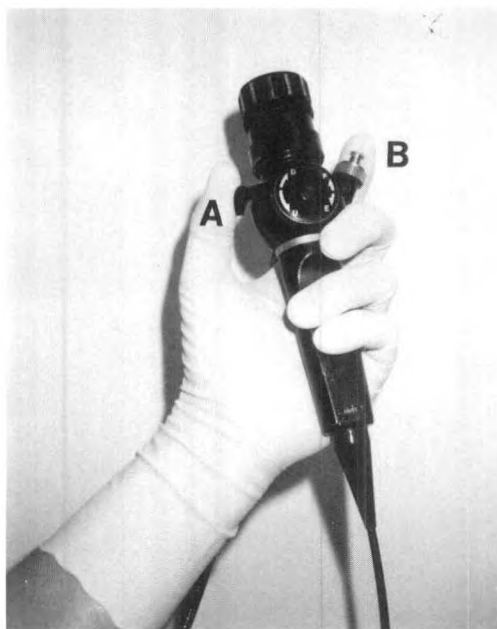


Figure 2. Position of the hand on the control section of the scope. A, Thumb over the angle bend lever. B, Index finger over the suction port.

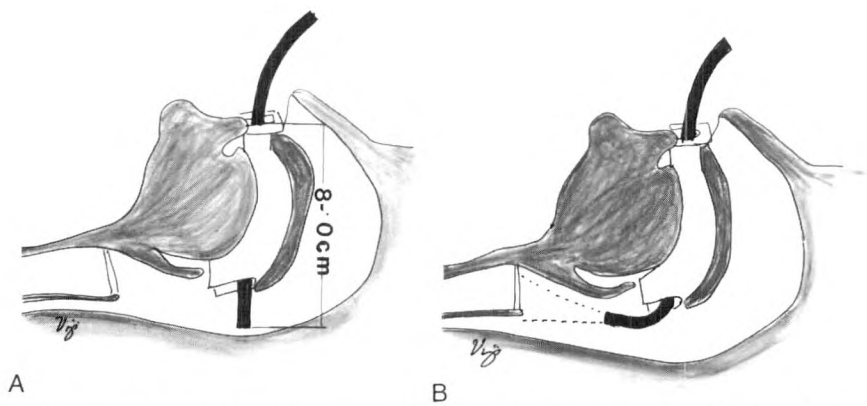
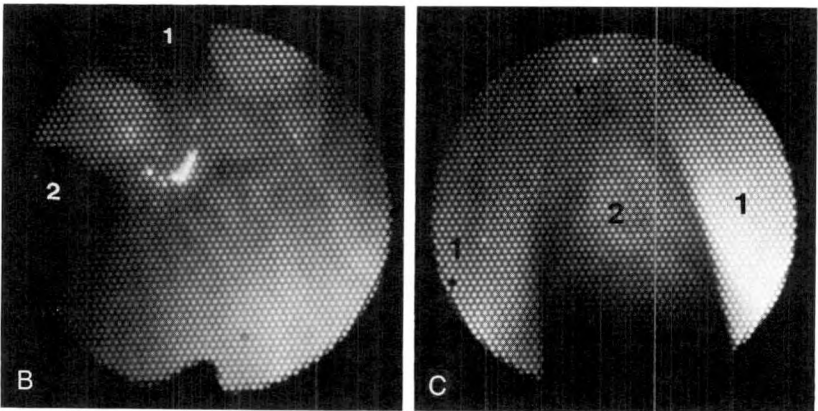


Figure 3. Important steps to visualize the larynx. A, Position: midline. Depth: 8–10 cm through the mouth. B, Upward angle bend.



Figure 4. A, Slight internal rotation of the insertion tube will guide the tip into the midline. B, Structures seen when the insertion tube is not in the midline: 1, Larynx. 2, Pyriform fossa. C, View after internal rotation of the insertion tube and slight increase in angle bend. 1, Vocal fold. 2, Glottis.



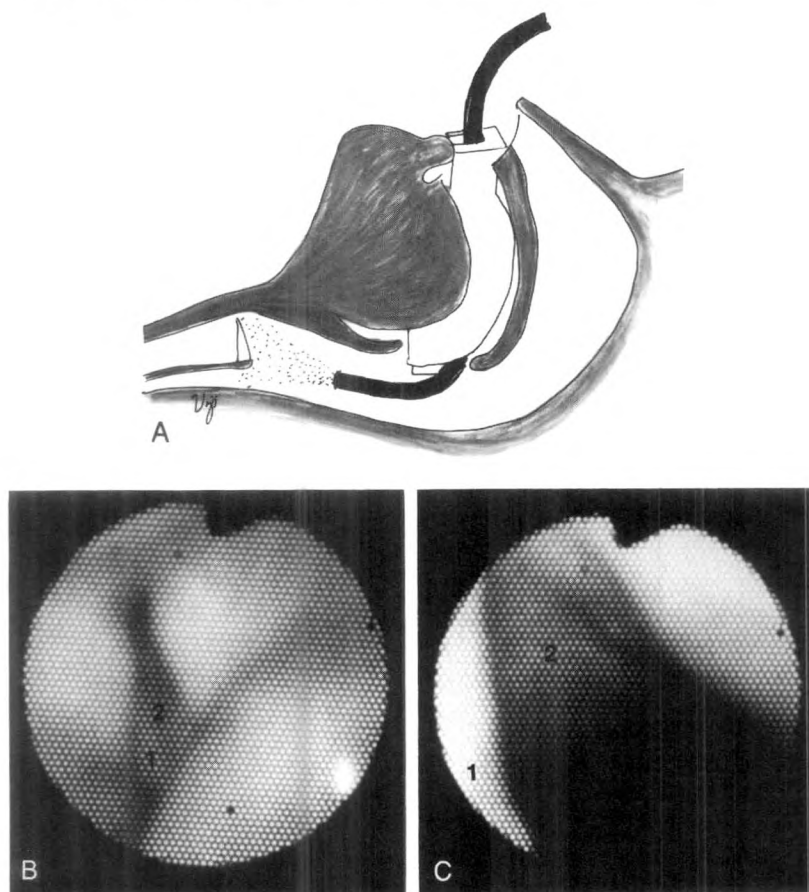


Figure 5. A, Through the suction port or the operating channel of the endoscope, a local anesthetic agent can be instilled to anesthetize the larynx. B, View of the larynx before the instillation of the local anesthetic agent. C, After instillation (1, vocal folds; 2, glottis).

oropharynx in the midline, making sure the tip deflects upwards in the center.

The endoscope is then advanced slowly, keeping the view of the larynx in the middle. With minor manipulation, the scope is placed in between the vocal cords, and advanced further into the larynx. The pale structure visualized immediately is the thyroid cartilage. Bring the distal end to neutral position, and advance the scope to identify the tracheal cartilages and the carina. If the patient responds to the scope in the trachea, further instillation of the local anesthetic through the scopes channel will facilitate threading the endotracheal tube.

The position of the endotracheal tube is assessed by looking through the scope, as one withdraws the insertion tube. Advancement of the endotracheal tube over the scope into the trachea may be difficult, especially through the mouth. Because of the acute angle formed by the scope as it enters the larynx (Fig. 6), the tip of the endotracheal tube impinges on the

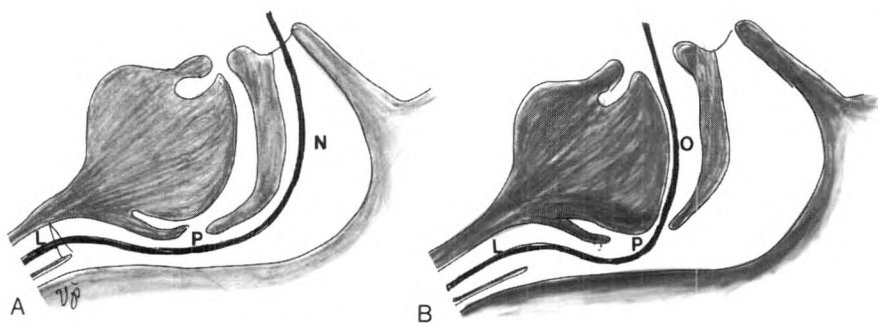


Figure 6. A, Visualizing the larynx and threading the endotracheal tube during nasotracheal intubation is relatively easier because the insertion tube adopts a natural curve during its passage through the nasopharynx (N), pharynx (P), with the larynx (L). B, During orotracheal intubation, advancing the endotracheal tube is difficult over the endoscope, due to the acute angle that the endoscope adopts as it passes through the oropharynx (O), pharynx (P), and the larynx (L).

arytenoid as one threads the endotracheal tube over the scope. In some cases, the bevel gets caught at the aryepiglottic fold. In situations where the endotracheal tube is much stiffer, and larger in diameter than the scope, the endotracheal tube is prone to enter the oesophagus, pulling the scope out of the trachea. Most of the difficulties are overcome by using the appropriate size endotracheal tube and scope. Advance the tube from the angle of the mouth to avoid the epiglottis in the midline. A slight internal rotation of the endotracheal tube, combined with the forward displacement of the tongue and the mandible will usually disengage the tube and allow it to slide through the vocal cords. It is essential to remember that when advancing or withdrawing the scope, the tip of the insertion tube should be in neutral position, to prevent damage to distal bending mechanism and the endoscopic fibers. Nasotracheal intubation is attempted after topical vasoconstrictor such as cocaine or phenylephrine are instilled into both nostrils. It is often helpful to pass the fiberoptic endoscope through a soft, well-lubricated nasal airway that is split lengthwise (Fig. 7). Once the insertion tube is advanced into the trachea, the airway is removed and the endotracheal tube is threaded over the insertion tube. Retraction of the tongue or protraction of the mandible may facilitate visualization of the larynx by lifting the tongue and epiglottis away from the pharynx. Despite the potential for bleeding, nasotracheal intubation is usually easier than orotracheal intubation because of the midline position. The insertion tube adopts a smooth natural curve as it enters the larynx. It is well tolerated by the patients and has minimal cardiovascular changes. Nasotracheal intubation is limited by the size, length, and availability of the endoscope.

The most frequent complaint of the beginning endoscopist is "everything looks pink, red or white." When that happens, the first reaction is to move the distal end up and down repeatedly, and vigorously, while simultaneously advancing the insertion tube without identifying the structures. If the endoscope advances easily, and greater than fifteen centimeters, and no defined structures are evident, it can be assumed that the

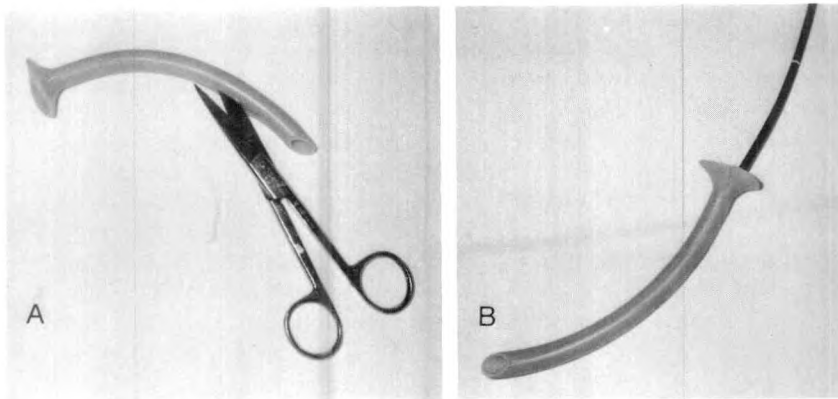


Figure 7. A, The nasal airway is slit longitudinally. B, The fiberoptic scope, with the nasal airway, is introduced into the nose in order to protect the lens from secretion and blood.

oesophagus has been entered. The most common cause for not being able to visualize the larynx is that the insertion tube is not in the midline, that it is too deep, or that the tip is facing the piriform fossa, pharynx or the buccal mucosa, which has no defined shape or borders. As a result, everything looks red with a ground glass appearance.

Fiberoptic endotracheal intubation requires more time in preparing and planning anesthesia, than the conventional rigid laryngoscopy. The patient, surgeon, and the operating room personnel must understand the need for the procedure, and the extra time required. The anesthetic technique is chosen on the basis of the patient's condition, the airway anatomy, the experience of the endoscopist and the type of the endoscopes available. Topical anesthesia and/or intravenous sedation may be used in scheduled elective surgeries, where the patients have normal airway or when difficulties are anticipated. Titrate both the local anesthetic agent and the sedation slowly, allowing sufficient time to take effect. Avoid local anesthetics in patients with full stomachs, to avoid aspiration. General anesthesia is preferred by many patients for endotracheal intubation. Use of an endoscopic mask or binasal airway permits uninterrupted anesthesia and ventilation for tracheal intubation. It is especially advantageous when an experienced endoscopist is teaching the technique.

FIBEROPTIC ENDOSCOPIC INTUBATION IN PATIENTS WITH AN UNPREDICTED DIFFICULT AIRWAY

It is not uncommon to face a situation where difficulty to intubate after general anesthesia is induced, and the patient is given a muscle relaxant. If the difficulty to intubate is recognized before the tissue trauma by conventional rigid laryngoscopy, the patient is in stable condition, and an experienced fiberoptic endoscopist and appropriate equipment are available, it is reasonable and safe to proceed with fiberoptic endoscopic

intubation. General anesthesia is continued and an antisialagogue is administered. Depending on the availability of the endoscopic mask, endoscopic airway, or binasal airway, the patient can be intubated without interrupting ventilation and anesthesia (Fig. 8). Another alternative is to allow the patient to breath spontaneously, deepen the anesthesia, then intubate. If the procedure is elective, multiple intubation attempts with rigid laryngoscopy frequently result in tissue trauma, when there is no skilled fiberoptic endoscopist available, the solution is to simply terminate the procedure after discussing it with the surgeon. When the procedure is emergent, and the patient's condition is deteriorating, they are allowed to awaken, when the patient is not a candidate for fiberoptic endoscopy. Alternative methods of intubation are planned with the surgeon such as cricothyrotomy, rigid bronchoscopy, retrograde intubation, or tracheostomy.

FIBEROPTIC ENDOSCOPIC INTUBATION IN PATIENTS WITH A DIFFICULT AIRWAY

When previous anesthetic history and physical examinations of a patient indicates difficulty with endotracheal intubation, it is better to attempt fiberoptic laryngoscopy initially, rather than after traumatic conventional methods. The patient, surgeon, and operating room personnel must be informed of the potential problems. Alternative treatments, including the possibility of tracheostomy, must be discussed with the patient and surgeon. Operating room personnel should be informed, in order to have the instruments available. Unless contradicted, antisialagogues should be administered preoperatively to the patient, the anesthetic technique and the route of endotracheal intubation must be chosen on the basis of the patient's physical condition, airway anatomy, and the indications for endoscopy (Fig. 9). Narcotics and tranquilizers can be used alone or in combination. Because a patient's responses are so variable, the drugs are best administered intravenously in the operating room, and should be precisely titrated, in order to get the maximum cooperation from the patient. Local anesthetic agents may be applied topically, through the inhaler, by infiltration, or instillation. General anesthesia and muscle relaxants are administered only after confirming the position of the endotracheal tube in the trachea.

COMPLICATIONS OF FIBEROPTIC ENDOSCOPY

Complications, like sore throats, hoarseness, tissue trauma, bleeding, laryngospasm, bronchospasm and aspiration, are the same as with conventional laryngoscopy. Despite all of the disadvantages, fiberoptic endoscopic intubation can be very successful. Experience is gained by merely following the technique step by step, paying attention to minor details and by exerting extra patience and perseverance (Table 1).

ADVANTAGES AND DISADVANTAGES

Fiberoptic endoscopic intubation is well tolerated by the patient. It is less traumatic, with minor cardiovascular effects, whereas in the conven-

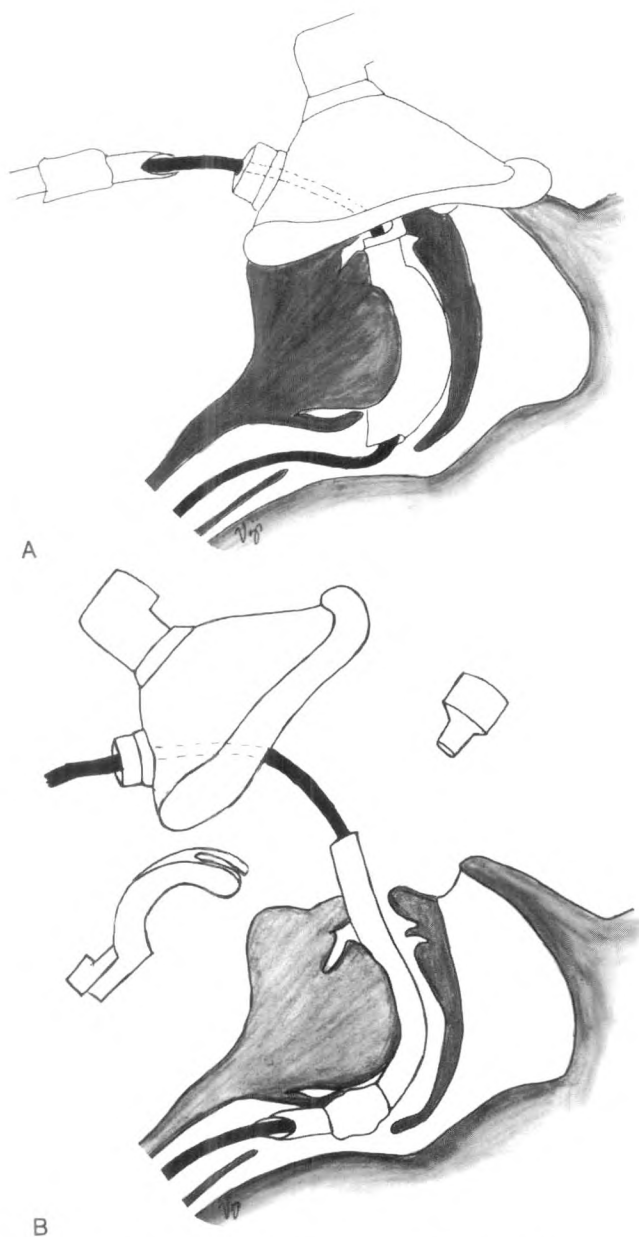


Figure 8. A, B. The endoscopic mask and airway facilitates oral endotracheal intubation under general anesthesia.

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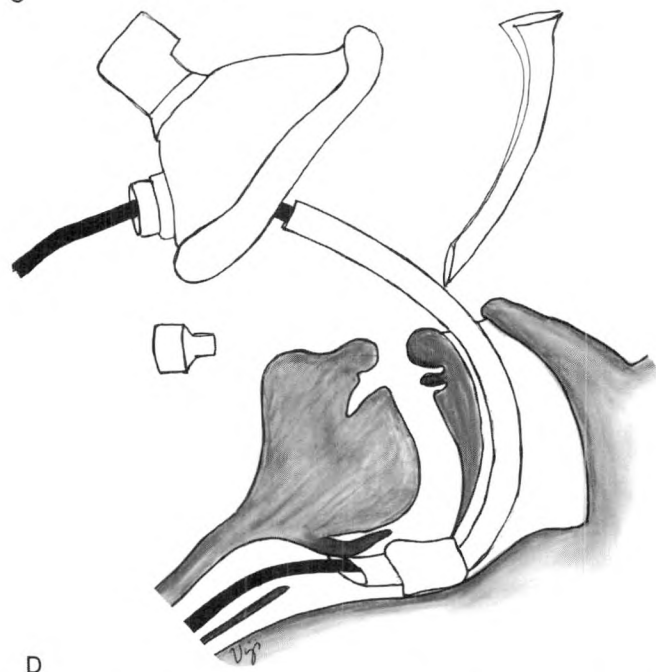
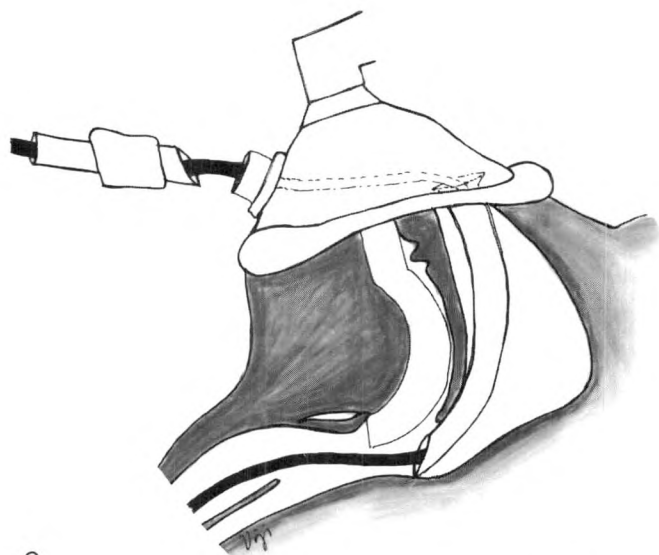


Figure 8 (*Continued*). C, D, Nasotracheal intubation, with fiberoptic scope, under general anesthesia.

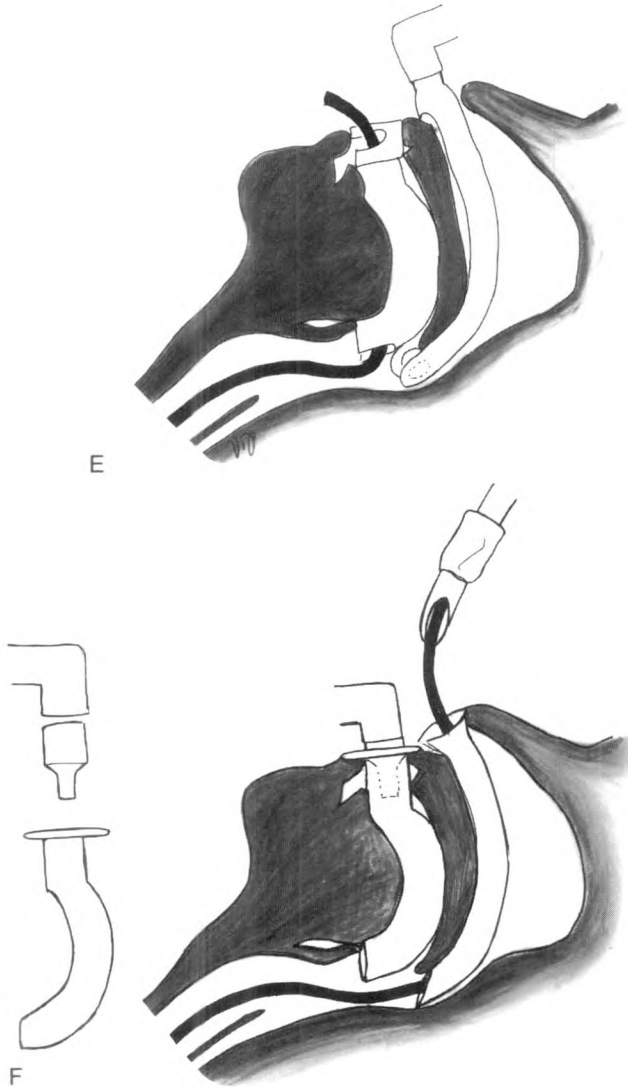


Figure 8 (*Continued*). E, General anesthesia, with the binasal airway, is used to perform oral endoscopic intubation. F, Nasotracheal intubation can be performed under general anesthesia by utilizing the oral airway with the endotracheal tube connector. Using a longitudinally split nasal airway to introduce the scope protects the lens.

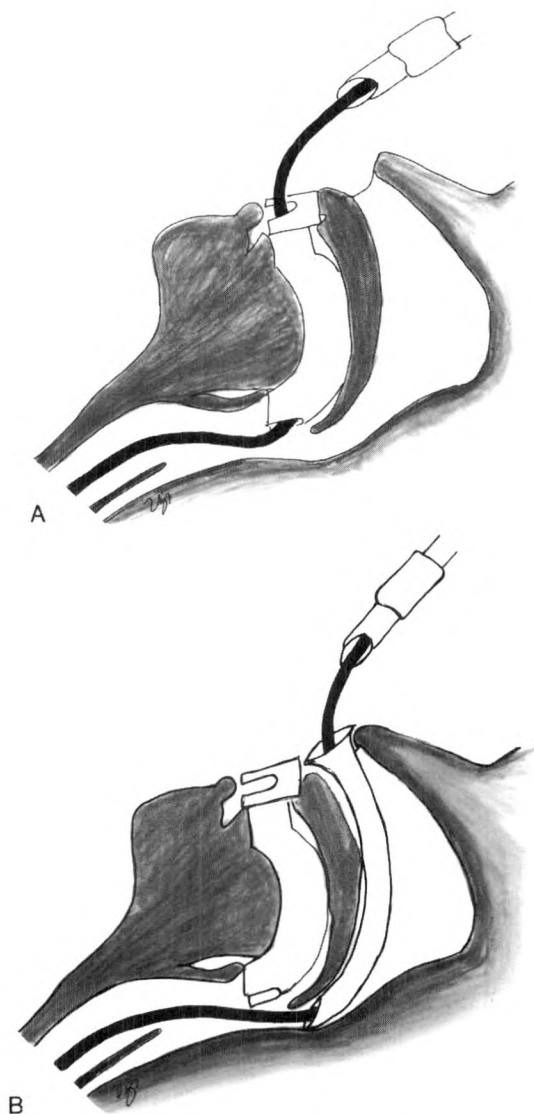


Figure 9. A, Endoscopic airway prevents the patient from biting, maintains the insertion tube in the midline, and retracts the tongue and the epiglottis from the pharynx during orotracheal intubation with local anesthesia. B, Nasotracheal intubation, with local anesthesia, utilizes the endoscopic airway and the longitudinally split airway.

tional, rigid laryngoscopy, it is impossible or difficult. The instruments are delicate and expensive to buy and maintain. Damage is inevitable with rough handling. Replacement of the broken fiberoptic fibers results in replacement of the entire insertion tube. Severe bleeding and copious secretions distort the vision. Fiberoptic technique requires more time than the conventional intubation with rigid scope. An assistant is mandatory to

Table 1. Keys to Successful Fiberoptic Endoscopic Intubation

Check both the light source and the endoscope
Apply an antifog agent to lens
Focus lens prior to use only
Lubricate insertion tube, avoiding lens
Cut endotracheal tube to correct length
Thread endotracheal tube over insertion tube
Introduce insertion tube into oropharynx, maintaining in midline
Advance endoscope 8 to 10 cm orally, or 12 to 14 cm nasally
Look through the scope and identify structures
Flex the tip of the endoscope upward to visualize larynx
Instill local anesthetics as needed through suction channel
Turn distal end of insertion tube towards midline if necessary
Enter glottis, return tip of endoscope to neutral position, and advance
Place the endoscope just above carina
Advance endotracheal tube into trachea
Withdraw endoscope with tip in neutral position
Check the position of endotracheal tube as you withdraw the scope

help with the procedure and to monitor the patient. It is less than ideal to perform fiberoptic endoscopic intubation in other than an OR or intensive care unit setting.

In addition to endotracheal intubation, the fiberoptic endoscope is used in many clinical situations that insure better patient care. Fiberoptic endoscopic intubation is simple and safe, once one masters the technique. This can be achieved through patience, practice, and perseverance, without compromising the care of your patient. Small setbacks should not deter one from practicing this technique, and getting help from experienced endoscopists. Every anesthetist who masters this modern nontraumatic technique, of endotracheal intubation, becomes an enthusiast of managing a difficult or impossible airway patient.

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Address reprint requests to

Viji Patil, MD
Department of Anesthesia
740 Adams Street
Syracuse, NY 13210

Fiberoptic Endobronchial Intubation

William E. Hurford, MD*

The need for skill in endobronchial intubation has grown along with the increased activity in cardiothoracic and tracheal surgery. Complex surgical procedures, such as bronchoplasty and resections of the trachea and carina, have mandated the development of reliable techniques to insure and protect the airway. Selective endobronchial intubation is now used routinely to provide a quiet field for the thoracic surgeon, to maintain continuity of the airway during tracheal and bronchial resections, and to limit the spread of secretions, infection, or pulmonary hemorrhage.²⁰ Endobronchial intubation also enables the anesthetist to electively collapse the lung, providing better access to the thoracic aorta during aneurysm repairs and access to the left heart during mitral valve repairs via a left thoracotomy approach.

Historically, endobronchial intubation has been performed by anesthesiologists in a "blind" manner, relying on physical signs such as breath sounds and chest movements to confirm proper placement of the endobronchial tube. While this technique is satisfactory in many cases, sometimes blind endobronchial intubation is difficult or impossible. As a result of a poorly positioned endobronchial tube, operating conditions may suffer or a variety of life-threatening complications may occur. In addition, recent studies have demonstrated that the physical signs used to confirm endobronchial tube placement can be unreliable.^{1-3, 12, 15} Upper lobe obstruction may occur frequently when blind techniques are used.¹²

Fiberoptic bronchoscopy has become increasingly popular for aiding endobronchial intubation.^{14, 15} Several authors have argued that the technique should be used routinely for endobronchial intubation.^{1, 15} While this position remains controversial, it is clear that the thoracic anesthetist needs to be skilled in fiberoptic bronchoscopy. Besides aiding and confirming the placement of single and double-lumen endobronchial tubes, fiberoptic bronchoscopy is useful for placing endobronchial blockers, removing secretions, changing the position of the endobronchial tube intraoperatively, and assessing airway patency during and after surgical repair. Fiberoptic tech-

*Assistant Professor of Anesthesia, Harvard Medical School; Assistant Anesthetist, Massachusetts General Hospital, Boston, Massachusetts

niques may also aid in safely changing a double-lumen to a single-lumen endotracheal tube at the conclusion of a case (Table 1). The thoracic anesthetist should therefore have a thorough knowledge of tracheobronchial anatomy and the techniques of fiberoptic-assisted endotracheal and endobronchial intubation.

TRACHEOBRONCHIAL ANATOMY

The adult trachea is approximately 10- to 13-cm (mean 11 cm) long and composed anteriorly and laterally of approximately 20 U-shaped cartilaginous rings and posteriorly by the trachealis muscle.^{6, 19} Identification of the flat trachealis muscle which forms the posterior wall of the trachea helps the endoscopist orient the endoscopic image. The internal diameter of the trachea averages 2.3 cm laterally and 1.8 cm anteroposteriorly.

At the carina, the trachea divides into right and left mainstem bronchi which in turn branch into eighteen segmental bronchi.¹³ The right mainstem bronchus divides at an angle of approximately 20 degrees from vertical, as opposed to 50 degrees for the left mainstem bronchus, and has an average length of 1.2 cm (approximate range one to four centimeters). The bronchus to the right upper lobe takes off laterally and superiorly from the right mainstem bronchus and then divides into bronchi supplying the apical, anterior and posterior segments of the right upper lobe. The bronchus intermedius extends 2 to 4 cm distal to the take-off of the right upper lobe bronchus. At this point, the middle lobe bronchus opens anteriorly, dividing into medial and lateral segmental branches. Almost immediately distal and posterior to the middle lobe bronchus is the opening to the superior segment of the lower lobe and then the confluence of the four bronchi to the medial, anterior, lateral, and posterior basal segments.

The left mainstem bronchus is narrower and longer than the right. It averages 5 cm in length (range, 3 to 7 cm) and bifurcates into upper and lower lobe bronchi, which are nearly equal in size. This bifurcation usually lies obliquely. The bronchus to the upper lobe divides almost immediately into the lingular bronchus, supplying the superior and inferior segments of the lingula, and the upper lobe bronchus supplying the anterior and combined apical-posterior segments. The bronchus to the lower lobe is a continuation of the left mainstem bronchus and divides into the bronchus to the superior segment and the confluence of the anterior, lateral, and posterior basal segments.

Table 1. Role of Fiberoptic Bronchoscopy in Thoracic Anesthesia

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| <ol style="list-style-type: none"> 1. Placement of double-lumen endobronchial tubes. 2. Confirmation of double-lumen endobronchial tube placement. 3. Placement of endobronchial blockers. 4. Removal of secretions. 5. Changing position of endobronchial tube intraoperatively. 6. Intraoperative endobronchial intubation. 7. Assessment of airway patency after surgical repair. 8. Changing endobronchial and endotracheal tubes. |
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ENDOBRONCHIAL TUBES

These specialized tubes initially were developed for differential bronchspirometry and the control of unilateral pulmonary hemorrhage and secretions. In current use, they permit selective ventilation of each lung, providing a quiet, collapsed lung upon which to operate while isolating the nonoperative lung from blood and secretions.²⁰ Most importantly, endobronchial tubes maintain an intact airway during unilateral bronchial resections.

Robertshaw Double-Lumen Tubes

Robertshaw tubes are made of red rubber and are available in left or right-sided versions.¹⁶ The right-sided version has a slotted bronchial cuff to accommodate the bronchial orifice to the right upper lobe. The tubes have large-diameter, low-resistance lumens and no tracheal hook. Small, medium, and large sizes, corresponding to 8-, 9.5-, and 11-mm endotracheal tubes, are available from Rüsch (New York, NY) and in the past from Leyland (London, England).

Disposable, polyvinyl chloride versions of the Robertshaw tube are available from several manufacturers: Rüsch (Bronchial Double-Lumen Tubes), Sheridan (Sher-I-Bronch, Argyle, NY), and Mallinckrodt (Bronchocath, St. Louis, MO) in 35, 37, 39, and 41 French sizes. Sheridan also produces a 28 French size. The greater variety of sizes may permit a better fit. These tubes are expensive, not reusable, and more difficult to place correctly. The elimination of cleaning and sterilization problems, however, has led to the widespread acceptance of disposable models.

Insertion of Robertshaw Tubes

Prior to intubation, the cuffs of the tube are checked for leaks, the tube lubricated, and a stylet placed in the bronchial lumen. The nonoperative or dependent lung should be chosen as the lung to be selectively intubated. If this is done, the endobronchial tube will not interfere with resection of the mainstem bronchus should this be necessary. If the nondependent lung is intubated, mediastinal compression or surgical manipulation may displace the bronchial limb and interrupt isolation of the operative lung. Mediastinal compression may also push the tracheal lumen against the tracheal wall creating a ball-valve obstruction to ventilation.

For laryngoscopy, a Macintosh blade is preferred over a Miller blade as it provides more room for manipulating the tube within the pharynx. Double-lumen tubes have a compound curve: the upper shaft of the tube curves anteriorly while the distal tip curves laterally. Intubation must therefore be systematic. First, the tube is placed in the oropharynx with the concavity of the distal tip facing anteriorly. Once the tip of the tube has passed through the cords, the tube is gently rotated so that the concavity of the main shaft faces anteriorly. The tube then is slid off the stylet until it is seated with its tip in the bronchus and its bite block between the patient's incisors.

Confirming Position of the Tube

The position of the tube must be checked carefully after insertion and again after positioning the patient to ensure that the correct lung can be isolated. Even if the placement of the endobronchial tube is to be confirmed with the bronchoscope, the following maneuvers should be performed to ensure proper lung isolation and function of the bronchial and tracheal cuffs (Table 2).

(1) Chest movements should be observed and breath sounds auscultated bilaterally prior to inflation of the cuffs. A moderate leak around the tube should be detectable. Inflation of the tracheal cuff with 5 to 10 cm³ of air should produce an airtight seal.

(2) The tracheal limb of the Cobb connector is clamped, the cap of the tracheal limb removed, and the bronchial cuff inflated to produce an airtight seal with minimal cuff volume (3 to 5 cm³ of air). Lung compliance should not decrease excessively, assuming that the compliance of each lung is relatively equal.

(3) The tracheal limb is then recapped, the clamp removed and placed on the connector to the bronchial limb, and the cap on the bronchial limb is removed. Next, the patient is ventilated only through the tracheal side of the Robertshaw tube. The chest should move and breath sounds should be heard only on the nonintubated side. No air should leak from the open bronchial port. Again, lung compliance should not decrease excessively.

Table 2. *Blind Confirmation of Double-Lumen Tube Placement*

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|----|---|
| 1. | Confirm tracheal placement of tube
Observe chest rise and fall.
Auscultate stomach and chest.
Monitor end-tidal CO ₂ .
Slowly inflate tracheal cuff until air leak around tube disappears.
Leak should disappear with <10 cc air.
If minimal leak—tube may be too large.
If >10 cc air required—cuff torn or tip of tube may be in trachea. |
| 2. | Inflate and check bronchial cuff
Clamp tracheal limb of Cobb connector, uncap tracheal port.
Apply positive pressure.
Slowly inflate bronchial cuff until air leak from tracheal port disappears.
Leak should disappear with 3 to 5 cc air.
If minimal leak—tube may be too large or inserted too far.
If >5 cc air required—cuff torn or tip of tube may be in trachea. |
| 3. | Confirm endobronchial placement
Apply positive pressure; observe chest rise and fall.
Auscultate chest, assess compliance.
Wrong side intubated—withdraw tube and gently re-advance.
If compliance is low—tube may be kinked, try withdrawing slightly, then readvance if necessary. |
| 4. | Confirm patency and position of tracheal lumen
Recap tracheal port and unclamp tracheal limb of Cobb connector.
Clamp bronchial limb of Cobb connector and uncap bronchial port.
Apply positive pressure.
Continue ventilating; observe chest rise and fall; auscultate chest, assess compliance.
Wrong side intubated—withdraw tube and gently re-advance.
If compliance is low—tube may be kinked, try withdrawing slightly, then readvance if necessary. |
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(4) Finally, ventilation through both lumens is checked once again. The bronchial cuff should be left inflated from the time of insertion until differential ventilation is no longer needed. Keeping this cuff inflated minimizes changes in the tube's position. We have not observed airway trauma from keeping the bronchial cuff inflated during this limited time, probably because the cuff is inflated only to minimal occlusion pressure and intraoperative movement of the tube is minimized.

Carlens and White Double-Lumen Tubes

The Carlens tube is designed for left-sided endobronchial intubation; the White tube is a right-sided version. Carlens and White tubes are constructed of red rubber and available in 35, 37, 39, and 41 French sizes. They have lumens of smaller internal diameter than the Robertshaw tubes and a carinal hook. The hook, while increasing the stability of the tube, makes the tube difficult to insert. Also because of the hook, the tube must be withdrawn back into the trachea before carinal surgery or pneumonectomy can be performed. These tubes are no longer in widespread clinical use.

Insertion of the Carlens or White tube. After laryngoscopy, the tube is placed in the oropharynx so that the concavity of the distal tip is anterior. Once the tip passes between the cords, the tube is rotated so that the carinal hook is anterior and can pass between the cords. Once the hook is beyond the larynx, the tube is rotated back 90 degrees so that the concavity of the shaft is anterior. The tube is then slid off the stylet and advanced until its hook engages the carina. The position of the tube is checked using the procedure outlined above for the Robertshaw tube.

Bronchial Blockers

When endobronchial intubation is difficult, as in pediatric or some laryngectomized patients, a No. 8 to No. 14 Fogarty venous occlusion catheter (10-cc balloon volume), placed with the aid of a fiberoptic bronchoscope and then inflated, may be used to selectively occlude a mainstem or lobar bronchus. To do this, a Fogarty catheter is first placed through the vocal cords under direct vision. A standard endotracheal tube then is placed alongside the catheter. The tip of the catheter is positioned using the fiberoptic bronchoscope and inflated under direct vision until the bronchus is seen to be occluded. Inflation of the cuff of the endotracheal tube helps hold the blocker in place. Once one-lung ventilation is no longer necessary, the Fogarty catheter balloon may be deflated and removed without disturbing the endotracheal tube.

An endotracheal tube containing a small side channel through which a specially designed blocker may be passed recently has become available in North America (Univent Tube, Vitaid Ltd., Lewiston, NY) (Fig. 1).^{9,10} The endotracheal tube is placed in the usual fashion and the tube is rotated 90 degrees, moving the blocker toward the side of the thoracotomy. The blocker may then be advanced and positioned in either mainstem bronchus with the fiberoptic bronchoscope. The blocker has a high-volume (6 to 7 cc), low-pressure cuff and an open channel through which secretions may be suctioned or oxygen insufflated. While this endotracheal tube, with the

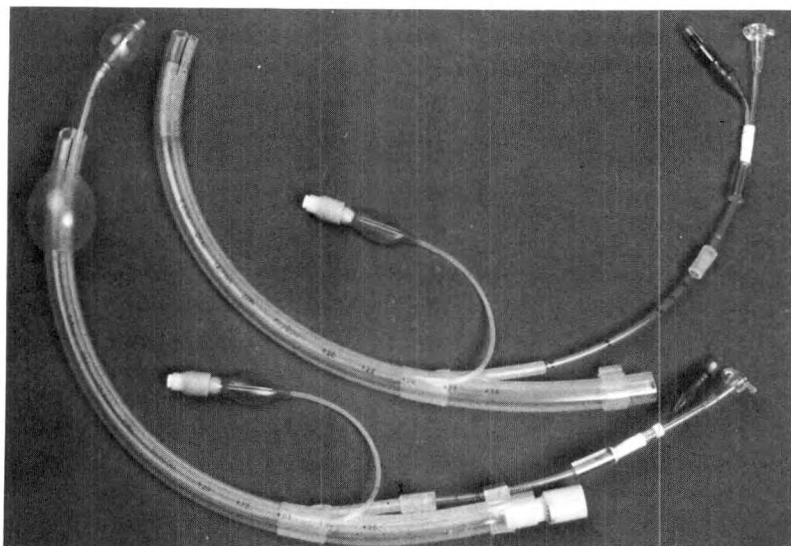


Figure 1. The Univent (Inoue) Tube. This endotracheal tube contains a small side channel through which a specially designed endobronchial blocker may be passed. In the figure, the tube on top demonstrates the blocker withdrawn into the main body of the endotracheal tube. On the bottom, the blocker has been advanced and the cuffs inflated. The endobronchial blocker has a high-volume, low-pressure cuff and an open channel through which secretions may be suctioned or oxygen insufflated. The blocker may be advanced and positioned within either mainstem bronchus. Position of the blocker is best confirmed by fiberoptic bronchoscopy. (Courtesy of Vitaid Ltd., Lewiston, New York)

blocker retracted into the main body of the tube, may be used for long-term intubations, the tube is made of silicone polymer and, as such, may be difficult to suction through using polyvinyl chloride suction catheters and difficult to secure using standard adhesive tapes. On the other hand, suction catheters may be passed more easily if they are first coated with a silicon lubricant and the tube can be secured with cotton tape. An important caution is that, except for a small metallic marker on the tip of the endobronchial blocker, the tube is radiolucent and difficult to identify with certainty on the chest radiograph.

Single-Lumen Endobronchial Tubes

If ventilation or suctioning of one of the lungs is unnecessary or unwise (i.e., the pneumonectomized patient or a patient with a bronchopleural fistula or massive intrapulmonary hemorrhage), endobronchial intubation with a single-lumen tube may be desirable. Specialized single-lumen endobronchial tubes, such as the Macintosh-Leatherdale tube for left-sided intubation or the Gordon-Green tube for right-sided intubation, have been developed but are rarely used in current practice. Long polyvinyl chloride or flexible armored tubes are usually used instead. A fiberoptic bronchoscope should be used to place these tubes in order to simplify placement and avoid obstruction of an upper lobe bronchus.

COMPLICATIONS OF ENDOBRONCHIAL INTUBATION

Poor positioning of the endobronchial tube with failure to isolate the operative lung is the most common problem (Figs. 2 and 3). Usually the endobronchial tube has not been passed far enough into the bronchus. This problem may occur when an inappropriately small tube is selected or when bronchial or tracheal narrowing prevents passage of an appropriately sized tube. The inflated bronchial cuff then rests at or above the level of the carina, producing partial or complete obstruction of the nonintubated bronchus. Gas trapping, with inability to deflate the operative lung, may occur. The tube also may be passed too far down a mainstem bronchus, resulting in obstruction of an upper lobe and hypoxemia. The wrong side may also be intubated. When the position of the tube is in doubt, it should be withdrawn and replaced.

The "margin of safety," or the distance between the most proximal and distal acceptable positions, for placing double-lumen tubes is relatively small and varies with the manufacturer and type of tube.^{2, 3, 11} For left-sided Mallinckrodt, Rüsch, and Sheridan tubes and medium left-sided Leyland Robertshaw tubes, the margin of safety is approximately 16 to 19 mm. For right-sided double-lumen tubes, the margin of safety varies greatly with the manufacturer's design. For medium Leyland, all Mallinckrodt, and large and small Rüsch double-lumen tubes, the margin of safety is 11, 7, 4, and 1 mm, respectively. While the Leyland double-lumen tube has the largest margin of safety, blind insertion of the tube is still associated with a 10% incidence of right upper lobe obstruction.¹² This incidence is much lower than the 89% incidence of right upper lobe obstruction noted after blind endobronchial intubation using right-sided Mallinckrodt tubes.¹²

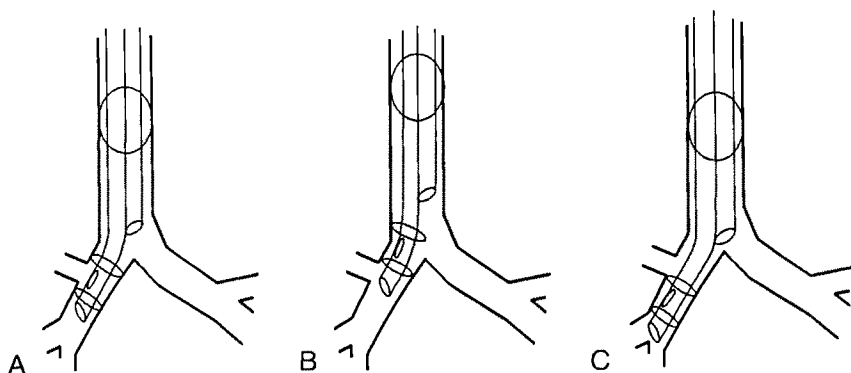


Figure 2. Correct and incorrect positioning of a right-sided double-lumen tube. A, Correct position. The endobronchial portion terminates above the bifurcation of the right middle and lower lobe bronchi. The right upper lobe bronchus is centered within the side slot of the endobronchial tube. The tracheal portion ends above the carina. B, The tube has not been inserted far enough. The endobronchial portion terminates at the carina. Ventilation through the tracheal lumen may be obstructed by the bronchial cuff. C, The endobronchial portion has been passed too far into the right main bronchus, placing the tracheal lumen past the carina. The right upper lobe will not be ventilated when the tracheal lumen is clamped. The right upper lobe bronchus may also be obstructed by the endobronchial cuff. The wrong mainstem bronchus may also be intubated (*not shown*).

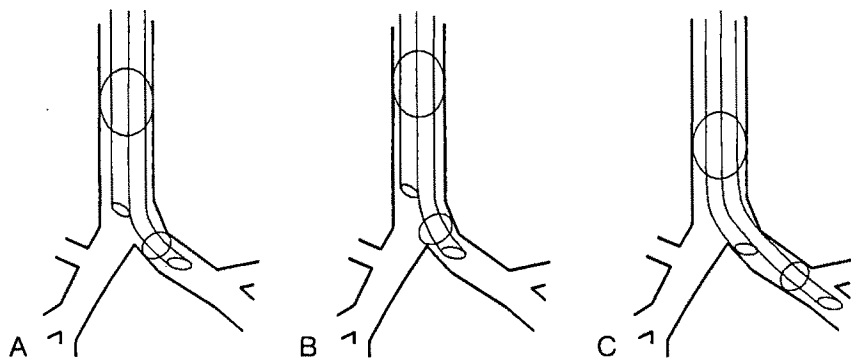


Figure 3. Correct and incorrect positioning of a left-sided double-lumen tube. A, Correct position. The endobronchial portion terminates above the bifurcation of the left upper and lower lobe bronchi. The tracheal portion ends above the carina. B, The tube has not been inserted far enough. The endobronchial portion terminates at the carina. Ventilation through the tracheal lumen may be obstructed by the endobronchial cuff. C, The endobronchial portion has been passed too far into the left main bronchus, placing the tracheal lumen past the carina. Ventilation of the right lung may be impossible. The wrong mainstem bronchus may also be intubated (*not shown*).

Bronchoscopic confirmation of the position of the tube theoretically should permit ideal placement of the tube in nearly all cases. But, the placement of the tube needs to be reconfirmed after patient positioning since movement of the patient's neck may alter the position of the tube. Saito and coworkers, for example, reported that left-sided Mallinckrodt tubes moved approximately 28 mm when the neck was flexed or extended.¹⁷

Laryngeal trauma and tracheal and endobronchial rupture, although rare, have been reported, presumably secondary to the large size of the endobronchial tube or overinflation of the cuffs.^{7,8} Using disposable polyvinylchloride tubes which have high volume, low pressure cuffs has not eliminated this problem.⁴

TECHNIQUES FOR FIBEROPTIC BRONCHOSCOPY

Choice of Bronchoscope

Ideally, the fiberoptic bronchoscope chosen should have an insertion cord with an outside diameter of 4 mm or less. The small diameter of the insertion cord will enable it to pass through both lumens of either small Robertshaw tubes or 35 French disposable double-lumen tubes. Bronchoscopes with larger diameter insertion cords may be used with larger endobronchial tubes. For fiberoptic-assisted intubation, a long insertion cord is necessary. Several suitable bronchoscopes are available.¹⁵ For our purposes, a bronchoscope such as the Olympus LF1 (Olympus Corp, Lake Success, NY) is ideal. The insertion cord is 4 mm in diameter, 60 cm long, and has a 1.2-mm working channel which, while small, may be used to clear secretions or insufflate oxygen. The bronchoscope also has an extra long fiberoptic cable leading to the light source. This feature is especially

convenient when using the bronchoscope intraoperatively under the surgical drapes. The Olympus BF 3C10 bronchoscope (insertion cord diameter, 3.6 mm) may also be used. Bronchoscopes with slightly thicker insertion cords, such as the Pentax FB-15A (Pentax Precision Instruments, Orangeburg, NY) (insertion cord diameter, 4.9 mm) will pass through both lumens of 41 French and the tracheal lumen of 39 French endobronchial tubes. No matter bronchoscope is chosen, it should be well lubricated with a silicon lubricant prior to its use to reduce the chance of damaging the plastic outer covering of the insertion tube.

Fiberoptic Confirmation of Endobronchial Tube Position

Fiberoptic bronchoscopy may be used to confirm the position of the endobronchial tube or assist with diagnosis of positioning problems in difficult cases. Several excellent review articles have recently been published which contain bronchoscopic color photographs of endobronchial tube positions and pertinent airway anatomy.^{14, 18} While Leyland Robertshaw tubes may be placed blindly with an acceptable degree of accuracy, disposable double lumen tubes tend to be more difficult. The position of this type of tube probably should be confirmed with the bronchoscope in all cases. Certainly, the small margin for error in the placement of currently available disposable right-sided tubes mandates bronchoscopic confirmation.

The procedure for confirming tube position with the bronchoscope is simple (Table 3). Ventilation can be continued during bronchoscopy since the bronchoscope may be inserted through an open port after the Cobb connector is clamped or through a bronchoscopic swivel adaptor. For left endobronchial intubation, after blind placement of the tube, the fiberoptic bronchoscope is inserted into the tracheal lumen (Fig. 4). The patency of the tracheal lumen is assessed while the insertion tube of the bronchoscope

Table 3. Fiberoptic Confirmation of Endobronchial Tube Position

After insertion of endobronchial tube and confirmation of position using "blind" technique:

For left endobronchial intubation:

1. Insert fiberoptic bronchoscope into tracheal lumen.
2. Assess patency of tracheal lumen.
3. Identify main carina and right mainstem bronchus. Proximal edge of bronchial cuff should be barely visible.
4. Remove fiberoptic bronchoscope and insert into bronchial lumen.
5. Confirm that the endobronchial portion of the tube terminates before the secondary carina of the left lung.
6. Adjust tube as necessary.

For right endobronchial intubation:

1. Insert fiberoptic bronchoscope into tracheal lumen.
 2. Assess patency of tracheal lumen.
 3. Identify main carina and left mainstem bronchus. Proximal edge of bronchial cuff should be barely visible.
 4. Remove fiberoptic bronchoscope and insert into bronchial lumen.
 5. Confirm that the endobronchial portion of the tube terminates before the secondary carina of the right middle and lower lobes.
 6. Slowly withdraw the fiberoptic bronchoscope until the slot for the right upper lobe is visualized.
 7. Check for patency of the right upper lobe. Adjust tube as necessary.
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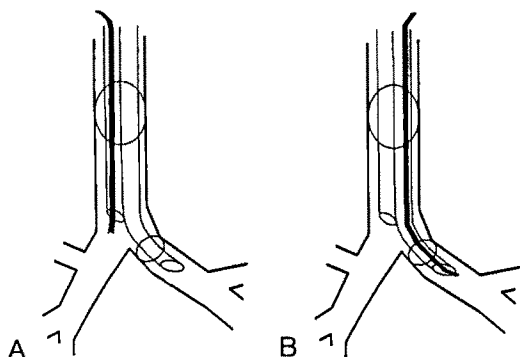


Figure 4. Fiberoptic confirmation of left-sided double-lumen tube position. *A*, The fiberoptic bronchoscope is inserted into the tracheal lumen. The main carina should be clearly visible distal to the end of the tracheal lumen. The right mainstem bronchus should be clear and unobstructed. The proximal edge of the endobronchial cuff of the tube should be barely visible at the carina. *B*, The fiberoptic bronchoscope is removed and inserted into the bronchial lumen. The secondary carina and the left upper and lower mainstem bronchi should be clearly visible and unobstructed.

is advanced under direct vision towards the carina. The main carina should be clearly visible distal to the end of the tracheal lumen. The right mainstem bronchus should be clear and unobstructed. The proximal end of the endobronchial cuff of the tube should be barely visible at the carina. The fiberoptic bronchoscope is next removed and inserted into the bronchial lumen. The patency of the bronchial lumen should be confirmed as the insertion tube of the bronchoscope is advanced. The secondary carina and the left upper and lower mainstem bronchi should be clearly visible and unobstructed.

The procedure is similar for right-sided endobronchial intubation (Fig. 5). After inserting the bronchoscope through the tracheal lumen, the main carina should be identified. Again, the proximal edge of the endobronchial cuff should be barely visible. The bronchoscope is then withdrawn and

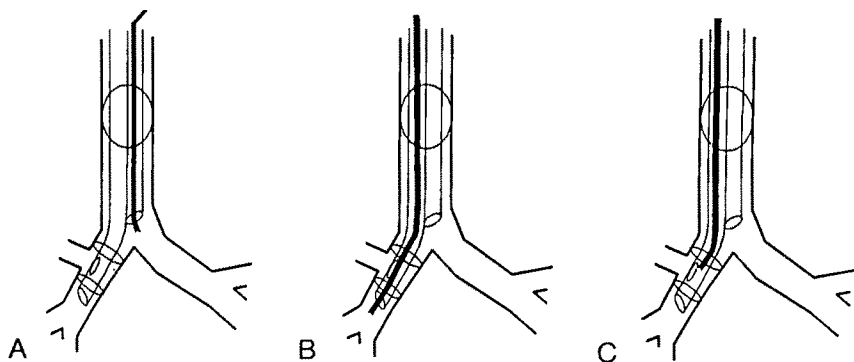


Figure 5. Fiberoptic confirmation of right-sided double-lumen tube position. *A*, The fiberoptic bronchoscope is inserted through the tracheal lumen. The main carina should be identified. The proximal edge of the endobronchial cuff should be barely visible. The left mainstem bronchus should be visible and unobstructed. *B*, The bronchoscope is inserted through the bronchial lumen. The secondary carina of the right middle and lower lobes should be clearly visible beyond the end of the tube. *C*, On withdrawing the bronchoscope slowly, the slot for the right upper lobe should be visualized. The right upper lobe bronchus should be centered within the slot.

inserted through the bronchial lumen. On passing the bronchoscope through the bronchial lumen, the patency of the lumen is confirmed. The secondary carina of the right middle and lower lobes should be clearly visible beyond the end of the tube. On withdrawing the bronchoscope slowly, the slot for the right upper lobe should be visualized. The right upper lobe bronchus should be centered within the slot.

The abnormality most often encountered is that the tracheal lumen will be partially kinked (Table 4). It will be difficult to pass the bronchoscope and the right mainstem bronchus will not be well visualized. If this is the case, then the wrong side may have been intubated or the tube may not have been passed beyond the carina. Slowly withdrawing the endobronchial tube under direct vision usually is sufficient to make the proper diagnosis. Reassessing the chosen size of the endobronchial tube may be necessary. Another common problem is failure to visualize the upper lobe bronchus. This may occur with either left- or right-sided intubations and is generally due to the tube being passed too far distally.

Fiberoptic-Assisted Endobronchial Intubation

The fiberoptic bronchoscope may also be used for initial placement of the endobronchial tube (Table 5). For this, the trachea is intubated with the endobronchial tube using either direct or fiberoptic laryngoscopy. If the trachea is to be intubated initially with the fiberoptic bronchoscope, the insertion cord is best placed through the bronchial lumen of the double-lumen tube. After confirmation of tracheal placement and adequate ventilation, the fiberoptic bronchoscope is advanced out through the bronchial lumen of the endobronchial tube and the main carina identified. For left endobronchial intubation, the tip of the insertion tube is advanced to a point just proximal to the secondary carina of the left upper and lower lobe bronchi. The double lumen tube is then advanced over the bronchoscope until the tip of the tube just comes into view or until resistance is felt. The endobronchial position of the tube is then confirmed. Next, the bronchoscope is removed and reinserted into the tracheal lumen. After assessing the patency of the tracheal lumen, the main carina and right mainstem

Table 4. Trouble-shooting with the Fiberoptic Bronchoscope

PROBLEM	CAUSE
1. Fiberoptic bronchoscope cannot be passed through tracheal lumen	1. Fiberoptic bronchoscope is too large or not well lubricated 2. Wrong side intubated 3. Double-lumen tube (DLT) kinked a. DLT too large b. DLT impacted on carina c. DLT not inserted far enough
2. Operative lumen not visualized	1. Wrong side intubated 2. DLT impacted on carina
3. Bronchial cuff not observed	DLT advanced too far
4. Bronchial lumen kinked	DLT impacted on carina
5. Wrong side seen	Wrong side intubated
6. Right upper lobe orifice not seen during right-sided endobronchial intubation	DLT inserted too far (common) or not far enough (uncommon)

Table 5. Fiberoptic-Assisted Endobronchial Intubation

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1. Intubate trachea with endobronchial tube.
 2. Confirm placement of the tube within the trachea using standard techniques.
 3. Insert fiberoptic bronchoscope through the bronchial lumen of the endobronchial tube.
 4. Identify main carina.
 5. For left endobronchial intubation:
 - a) Advance fiberoptic bronchoscope to just proximal to the secondary carina of the left lung.
 - b) Advance double-lumen tube over the bronchoscope until the tube just comes into view or resistance is felt.
 - c) Confirm that the endobronchial portion of the tube terminates proximal to the secondary carina of the left lung.
 - d) Remove fiberoptic bronchoscope and insert into the tracheal lumen.
 - e) Assess patency of tracheal lumen. Identify the main carina and right mainstem bronchus. Proximal edge of the bronchial cuff should be barely visible.
 - f) Adjust tube as necessary.
 6. For right endobronchial intubation:
 - a) Advance fiberoptic bronchoscope into the bronchus intermedius.
 - b) Advance double-lumen tube over the bronchoscope until the tube just comes into view or resistance is felt.
 - c) Confirm that the endobronchial portion of the tube terminates proximal to the secondary carina of the right middle and lower lobe bronchi.
 - d) Slowly withdraw the fiberoptic bronchoscope until the slot for the right upper lobe is visualized.
 - e) Check for patency of the right upper lobe. Adjust tube as necessary.
 - f) Remove fiberoptic bronchoscope and insert into the tracheal lumen.
 - g) Assess patency of tracheal lumen. Identify the main carina and left mainstem bronchus. Proximal edge of the bronchial cuff should be barely visible.
 - h) Adjust tube as necessary.
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bronchus are identified. The proximal edge of the endobronchial cuff should be barely visible.

Fiberoptic-assisted right-sided endobronchial intubation is similar. In this case, the tip of the bronchoscope is positioned within the bronchus intermedius and the tube is advanced until it just comes into view or resistance is felt. After confirming that the endobronchial portion of the tube terminates proximal to the secondary carina of the right middle and lower lobe bronchi, the bronchoscope is slowly withdrawn until the slot for the right upper lobe is visualized. The tube is adjusted so that the right upper lobe bronchus is positioned within the center of the slot. The bronchoscope is then removed and reinserted into the tracheal lumen. After assessing the patency of the tracheal lumen, the main carina and left mainstem bronchus are identified. The proximal portion of the endobronchial cuff should be barely visible.

OTHER USES FOR FIBEROPTIC BRONCHOSCOPY

Using similar techniques and landmarks, the fiberoptic bronchoscope can be invaluable in placing bronchial blockers and single-lumen endobronchial tubes.⁵ Endobronchial tubes and blockers displaced during surgery may be replaced with accuracy. Bronchoscopy also permits secretions to be removed and can provide a direct assessment of endobronchial anatomy

both intraoperatively and prior to extubation. Such an assessment of airway anatomy may be especially important after carinal resection and reconstruction or bronchoplasty.

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Address reprint requests to

William E. Hurford, MD
Department of Anesthesia
Massachusetts General Hospital
32 Fruit Street
Boston, MA 02114

Fiberoptics for Head and Neck Patients

Andrew Herlich, DMD, MD*

Head and neck surgery has the unique problem of the shared airway or surgery in close proximity to the airway. The preoperative pathology frequently precludes routine anesthetic induction techniques as well as routine orotracheal intubations. A common example of this problem is the patient requiring postoperative intermaxillary fixation with preoperative cervical spine trauma.² Flexible fiberoptic laryngoscopy is a necessary adjunct for the anesthesiologist to be able to establish a rapid, safe access to the tracheobronchial tree. Access may be limited by a mass, trauma, infection or anomaly which may have been acquired or congenital.^{1, 7, 9, 10, 16, 22, 32, 36, 39, 40, 55} Fiberoptics have also afforded the anesthesiologist to be a diagnostician in the preoperative, intraoperative and postoperative phases of patient care. For instance, the patient who has previously undiagnosed nasal polyps can be seen by the anesthesiologist during the fiberoptic endoscopy. Another example may be the diagnosis of singed nasal hair or previously occult inhalation injury.^{18, 49} By the use of the fiberscope, the trauma of a rapid, possible blind intubation may avoid the hazard of serious epistaxis or mucosal excoriation.^{18, 49} Soft palate motion may be easily assessed with a fiberscope as well as terminal eustachian tube anatomy and function.^{44, 45} Laryngeal and hypopharyngeal pathology may be assessed and carefully bypassed with skillful fiberoptic laryngoscopy.³⁶ Safe, rapid placement of an endotracheal tube may be aided by fiberoptic laryngoscopy in a patient who has a cut throat injury as alternative to a emergent tracheostomy in certain situations.⁷ These events must be coordinated with the responsible surgeon. Patients who have sustained significant injury of the craniofacial matrix also may have sustained injury to the cervical spine, thorax, abdomen, and extremities. Flexible fiberoptic laryngoscopy may safely aid in securing an airway in a patient with these problems.^{6, 25, 58}

Intraoperatively the flexible fiberoptic laryngoscope may safely assist

*Assistant Professor of Anesthesiology/Critical Care Medicine, University of Pittsburgh School of Medicine; Staff Anesthesiologist, Eye & Ear Hospital of Pittsburgh, Pittsburgh, Pennsylvania

the changing of endotracheal tubes, especially in those who have had nasotracheal intubations.^{14, 24, 52} Progressive increases in airway pressure, deleterious changes in oxygen saturation or end-tidal carbon dioxide may be diagnosed with the aid of the flexible fiberscope. Foreign bodies, herniated cuffs from endotracheal tubes, kinked endotracheal tubes or inadvertent mainstem intubations may all be assessed by the flexible fiberoptic laryngoscope.

After head and neck surgical procedures such as thyroidectomy or other excision of neck masses, the flexible fiberscope may help with the diagnosis of a patient in whom acute airway obstruction may occur from occult hematoma, vocal cord injury or surgical trauma.^{14, 20, 28, 41}

Extubation may be impeded by surgically induced anatomical changes or midface surgical wires placed during Le Fort-type Page osteotomies. The flexible fiberscope would aid the anesthesiologist in locating the point of impedance and appropriate surgical corrections may be made to allow for extubation of the trachea.²¹ The flexible fiberoptic laryngoscope has been utilized on numerous occasions as a means of identification of the otherwise obscured trachea prior to tracheostomy. Examples of these are postoperative patients with significant edema, postradiation soft tissue changes and those with obese or short necks. Such a diverse patient population present the head and neck surgeon with obscured landmarks which may be transilluminated by the use of the flexible fiberoptic laryngoscope.^{8, 32, 42}

BASIC APPROACH

Due to the majority of head and neck cases presenting with the need to avoid endotracheal tube placement in the oral cavity, the nasotracheal route is preferred by most surgeons at the Eye & Ear Hospital of Pittsburgh. The use of a flexible fiberscope via the nasotracheal route allows for less gagging by the patient in the event of incomplete topical anesthesia or the inability to adequately place topical anesthesia or incomplete sedation. Fiberoptic nasotracheal placement is relatively easy to accomplish and the awake patients seem to have a better acceptance than with the orotracheal route.^{6, 17, 30, 38, 50} As stated previously, the nasotracheal route allows for visual identification of the nasal cavity, its contents, posterior choanal orifice, eustachian tube, soft palate and nasopharynx.^{19, 44, 45} Additionally, the nasal route avoids the possible risk of tooth damage that may occur during a difficult orotracheal intubation.⁵

Premedication and Sedation

When the airway is not compromised and the risk of aspiration of abdominal contents is low, the premedication most frequently utilized at the Eye & Ear Hospital of Pittsburgh is a combination of midazolam and glycopyrrolate. This combination provides significant amnesia as well providing a potent antisialogogue. These are key points leading to the successful fiberoptic intubation. Previous reports have included a wide variety of parental sedatives as well as general anesthesia prior to attempting the flexible fiberoptic laryngoscopy.^{5, 11, 13, 25, 29, 30, 31, 32, 46, 47, 51}

After arrival in the operating room suite, intravenous access is obtained and monitoring with an automated noninvasive blood pressure device is established. In addition, electrocardiographic monitoring, precordial stethoscope, and pulse oximetry are established. The patient is maintained in the slightly head-up position at all times to reduce the likelihood of lax tissues of the oropharynx falling posteriorly and obstructing the airway. Supplemental sedation administered in incremental fashion is then begun. The supplemental sedation is timed to coincide with topical anesthetic placement in the airway. The agents most frequently used at the Eye and Ear Hospital of Pittsburgh for supplemental sedation are midazolam, fentanyl and droperidol.

Topical Anesthesia

The nasal mucosa is prepared with a mixture of lidocaine 1.5% and phenylephrine 0.25% to a total volume of 4 cc, which is sprayed in short bursts with a 22-gauge IV catheter into both nares. The lidocaine-phenylephrine mixture is chosen in order to avoid some of the negatives aspects of cocaine.¹² Despite preoperative examination of both nares, posteriorly there may be anatomical obstructions making the initially preferred nasal passage less useful than planned. In addition to the nasal spray, long, single-ended, cotton tip applicators placed into both nares with a small amount of the lidocaine phenylephrine spray on each applicator are utilized. Each applicator, over time is gently advanced until resistance is met or the applicator enters the nasopharynx. Each side of the nasal cavity should be able to accommodate at least four cotton tip applicators without trauma or difficulty. The process should take place over a 15 to 20 minute time course which allows for patient acclimation, increased doses of sedation, as well as achieving both the mechanical and pharmacologic reduction of the thickness of the nasal mucosa. The cotton-tip applicators are left in place until the fiberoptic endoscopy is begun.

At the same time nasal mucosa is being prepared for endoscopy, a lidocaine lollypop consisting of the contents of the 3-gram tube of lidocaine 5% ointment are placed on the patient's tongue. Over the 15–20 minutes that the nasal mucosa is being prepared, the oropharynx, tongue and hypopharynx are also topically anesthetized. In addition, the lidocaine lollypop helps to obtund the gag reflex. Finally, a transtracheal block is performed with a mixture of lidocaine 4% 2 mg/kg and tetracaine 2% 0.5 mg/kg. Tetracaine was utilized in the past in much higher doses with toxic reactions and leading to disfavor. The chosen dose is well below the toxic range. The chosen volume and concentration for the transtracheal block produces a relatively large aerosol with a profound anesthetic in terms of quality, quantity, density and spread through the periglottic regions, as well as the proximal tracheobronchial tree. Approximately 60–90 seconds after the transtracheal block is performed, the flexible fiberoptic endoscopy may begun. This particular approach to topical anesthesia requires the least number of injections in the neck as well as the least required mobility of the temporomandibular joint in order to place the oropharyngeal topical anesthesia. The low incidence of failure by the approach utilized by the anesthesia staff at the Eye & Ear Hospital of Pittsburgh is due to the fact

that the secretions and patent motion are minimized. In addition, the quiescent, cooperative patient also increases success with this approach with little significant alteration of heart rate, blood pressure, or respiratory rate.^{31, 46}

The occasional patient who presents with a difficult intubation as well as at increased risk for aspiration of abdominal contents is approached in a similar manner except for the reduced amount of sedation utilized and the deletion of the transtracheal block. The patient receives small amounts of local anesthetic delivered through the suction port of the flexible fiberoptic laryngoscope in close proximity to the glottis and trachea if needed.²⁹ However, if the patient with a difficult intubation and full stomach becomes an emergent situation or risks of aspiration become unacceptably high in relation to airway compromise, an awake tracheostomy utilizing local anesthesia should be considered.

Technical Aspects

In a practical and didactic approach, the endotracheal tube is placed over the flexible fiberoptic laryngoscope and advanced as far as possible to the most proximal area of the scope prior to insertion into the nares. This technique permits the maximal flexibility of the fiberoptic laryngoscope. It also permits complete assessment of the entire nasal cavity, the nasopharynx, an oropharynx as well as hypopharynx. Since the fiberscope is smaller than the endotracheal tube through which it has been placed, the likelihood of epistaxis or mucosal excoriation is reduced. Finally, the chances of the fiberscope entering the Murphy eye of the endotracheal tube are negated.²⁷

Caution

A word of caution is useful in the head and neck patient with a difficult airway prior to the application of topical anesthesia, sedation and actual flexible fiberoptic laryngoscopy. An experienced surgeon should be available to establish an emergent surgical airway if needed. Additionally, each anesthesia machine should contain a cricothyroid puncture kit and the proximity of a jet ventilation system adapted for cricothyroid puncture.

CASE PRESENTATIONS

In order to illustrate some of the practical applications, limitations, as well as the relative contraindications to the use of flexible fiberoptic laryngoscopy, a number of cases are presented for discussion. The flexible fiberoptic laryngoscope is a very important and necessary contribution to the anesthetic management in head and neck cases; however, its use should be applied carefully and deliberately.

Case 1

An 18-year-old woman presented for release of bilateral temporomandibular joint ankylosis secondary to previous trauma. (Fig. 1A, B, and C).

Three and one-half years prior to the present admission, the patient sustained bilateral mandibular fractures involving both the angles as well

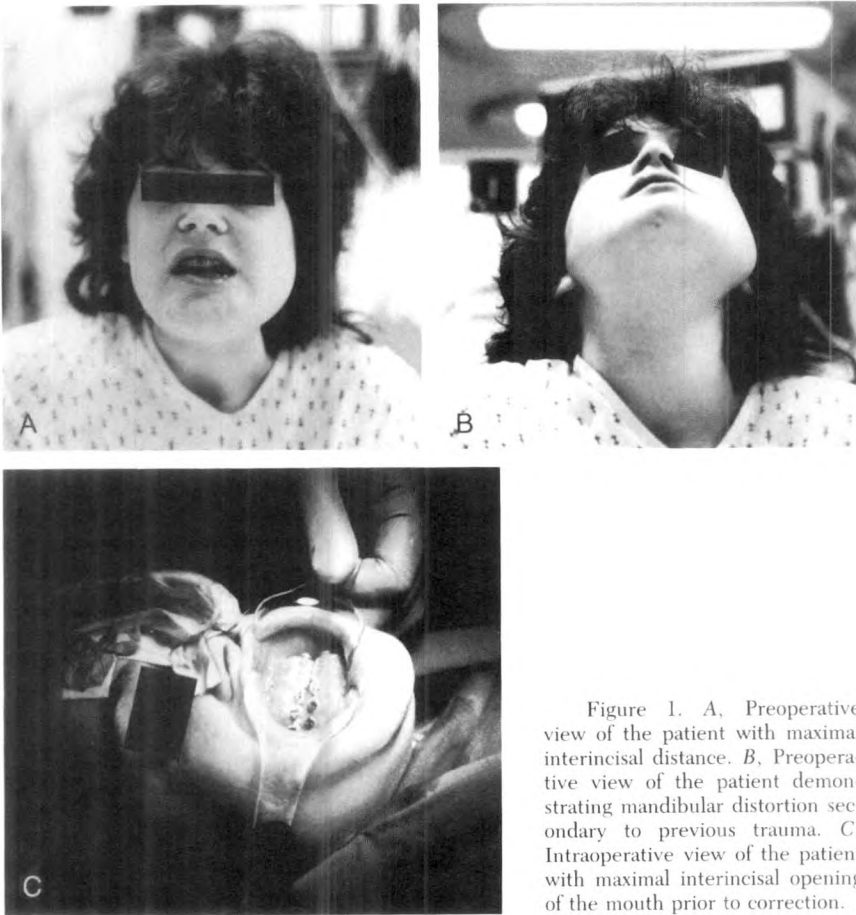


Figure 1. A, Preoperative view of the patient with maximal interincisal distance. B, Preoperative view of the patient demonstrating mandibular distortion secondary to previous trauma. C, Intraoperative view of the patient with maximal interincisal opening of the mouth prior to correction.

as the subcondylar regions. Severe soft tissue injuries of the neck, lower face, and tongue as well as the mandibular fractures necessitated emergent tracheostomy. Unfortunately, the emergent tracheostomy resulted in permanent thyroid dysfunction necessitating daily thyroid hormone replacement. Also at the time of the initial injury, the patient had significant cervical spine injuries necessitating urgent anterior cervical fusion. The patient recovered from the cervical spine fusion without neurological sequelae. The initial mandibular fractures were reduced with intermaxillary fixation. Unfortunately, after a period of one and one-half years from the time of the initial injury, the temporomandibular joints became ankylosed and bilateral release of the temporomandibular joint with cartilaginous rib grafts were planned and uneventfully accomplished. In the interim between the first temporomandibular joint surgery and the present admission, the patient experienced a progressive recurrence of the temporomandibular joint ankylosis so her ability to eat normal solid foods and articulate was altered. The patient's medical history otherwise was remarkable only for

elective cesarean section performed under spinal anesthesia one year prior to admission.

At the time of the present admission, the patient's pertinent physical examination was remarkable in that she appeared well nourished and well developed despite her limited oral function. Also remarkable was the patient's inability to open her mouth greater than 4 mm of interincisal distance. Using the previous described sedation and topical anesthesia techniques a successful nasal endotracheal intubation was accomplished utilizing the flexible fiberoptic laryngoscope. The surgical procedure involved the creation of pseudoarthroses as well as cartilaginous caps to allow for maximal condylar function. At the completion of surgery, passive mouth opening allowed for 35mm of interincisal distance. The nasotracheal tube was safely removed in the recovery room approximately 2 hours after the completion of surgery and after fiberoptic assessment of her airway had taken place. Her entire postoperative course was uneventful.

Ankylosis of the temporomandibular joint whether acquired or congenital is a strong indication of flexible fiberoptic intubation in the head and neck operating room suite.^{1, 47} Similar restrictions of mandibular motion maybe seen in hypertrophy of the coronoid process, fracture at dislocation of the zygoma or dysfunction of the muscles of mastication. The particular patient presented in this case benefited by the use of the flexible fiberoptic nasotracheal intubation without the need for perioperative tracheostomy.

Case 2

A 27-year-old woman with severe recurrent tonsillitis over an 8-month period presented for elective tonsillectomy. Two years prior to the scheduled procedure, the patient sustained bilateral mandibular fractures of both the angle and subcondylar regions. A repair of the fractures of the body consisted of bicancellous transosseous screws and cartilaginous rib grafts placed in the subcondylar regions. Subsequently, the patient developed progressive limitation of the ability to open her mouth. Ankylosis of the temporomandibular joint was suspected and interincisal distance was measured to be only 18 mm (Fig. 2).

The patient's past medical history was significant for insulin-dependent diabetes mellitus of 20 years' duration with adequate control using neutral protamine Hagedorn insulin 40 units each morning and 12 units each evening. The patient also had a history of recurrent episodes of bulimia the most recent of which occurred 1 and one half years prior to the scheduled tonsillectomy.

In the preoperative discussion with the attending otolaryngologist, it was agreed that a nasotracheal tube would permit the greatest access in order to perform the surgery with placement of the mouth gag. After appropriate sedation and topical anesthesia, a flexible fiberoptic nasotracheal intubation was easily accomplished. With a moderate degree of difficulty including a significant amount of force, the attending surgeon was able to open the mouth sufficiently to insert the mouth gag and perform the tonsillectomy. At the end of the 25-minute procedure, the general anesthetic was discontinued and the patient was transported to the recovery room. The trachea was extubated when the patient was fully alert and

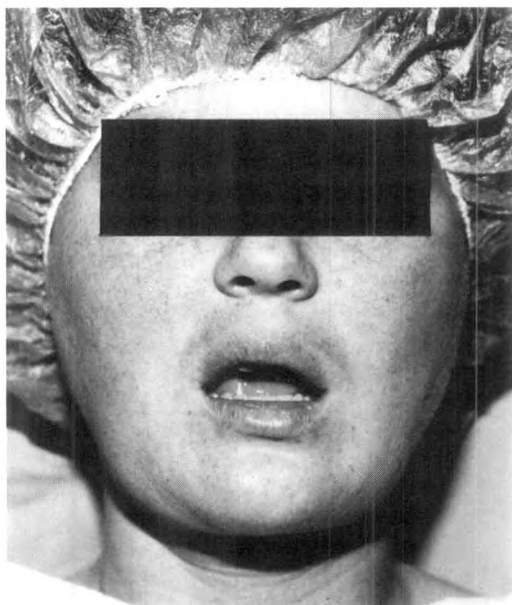


Figure 2. The patient's maximal interincisal distance prior to tonsillectomy.

without evidence of airway edema or trauma. The patient's recovery was uneventful and she was discharged from the hospital on the first postoperative day. Five months after the patient's tonsillectomy, she returned to the operating room for removal of dislodged mandibular osseous screws as well as the release and replacement of existing cartilaginous rib grafts due to further progression of the temporomandibular joint ankylosis. At the time of surgery the ankylosis was deemed to be 95% complete. The interincisal distance decreased from 18 to 12 mm in only 5 months. At the time of the second temporomandibular joint surgery, again fiberoptic intubation was used via the nasotracheal route without incident or difficulty.

The use of fiberoptic nasotracheal intubation for tonsillectomy and adenoidectomy has been described for the patient with obstructive sleep apnea only.²³ Use of fiberoptics has not been previously discussed to improve intraoral surgical access for tonsillectomy and adenoidectomy. Under the conditions of temporomandibular joint ankylosis, flexible fiberoptic nasotracheal intubation may permit successful surgical access without the encumbrances of an orotracheal tube.

Case 3

A 62-year-old woman presented for interstitial radioactive implants to the base of the tongue and floor of the mouth due to a recurrence of a squamous cell carcinoma. One year prior to the current admission, a partial glossectomy and bilateral radical neck dissection was performed. Postoperatively, the patient had a full course of external beam irradiation. During the interval between the completion of the external beam irradiation and the present admission, the patient was noted to have neck wound breakdown as well as her recurrence of her disease. Her past medical history

was significant only for 60 packs a year of cigarette smoking and occasional beer drinking. Her cigarette smoking ceased immediately prior to her initial resection.

The pertinent physical examination revealed an anxious, thin, but not cachectic individual. The patient had decreased temporomandibular joint mobility, a relatively immobile tongue and diffuse induration of the neck with areas of wound breakdown and slight serosanguinas discharge. (Fig. 3).

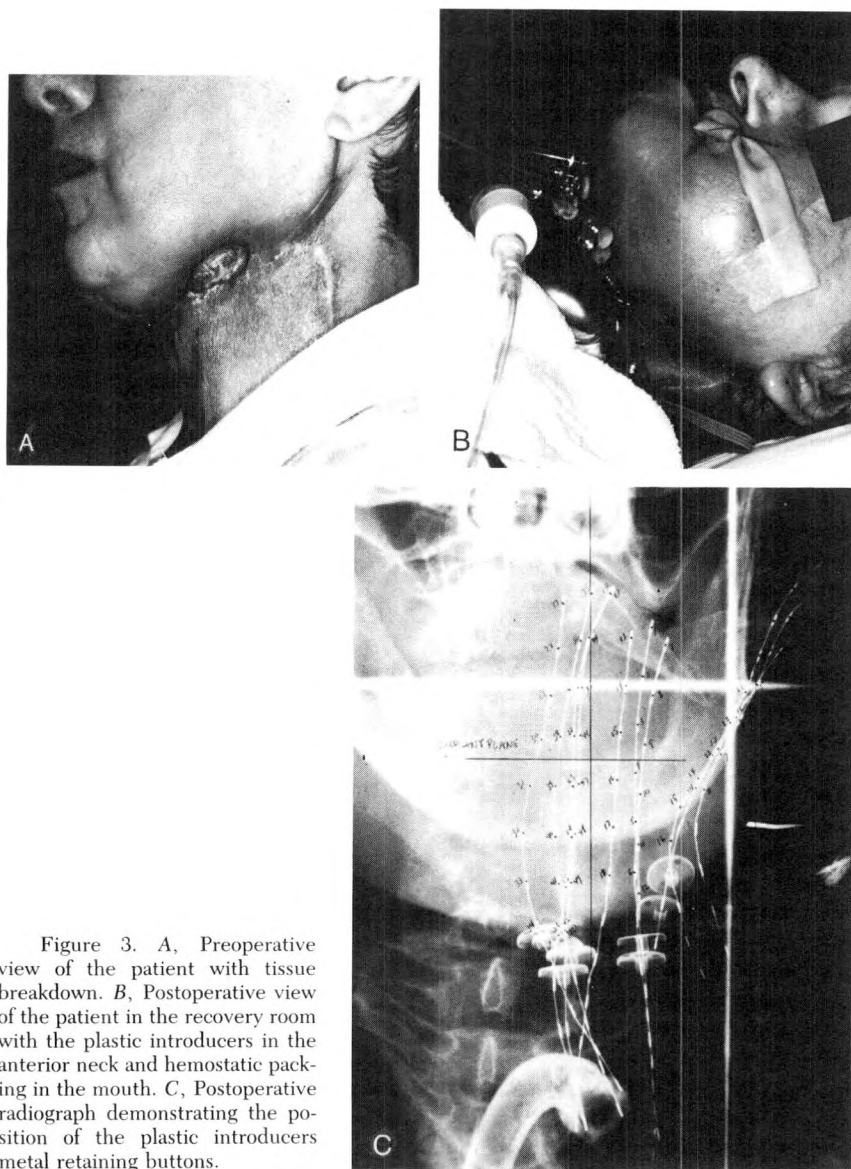


Figure 3. A, Preoperative view of the patient with tissue breakdown. B, Postoperative view of the patient in the recovery room with the plastic introducers in the anterior neck and hemostatic packing in the mouth. C, Postoperative radiograph demonstrating the position of the plastic introducers metal retaining buttons.

Her ability to articulate was poor and the remaining dentition was in poor repair. Due to the anticipated difficulties of orotracheal intubation as well as the type of surgical procedure, an awake nasotracheal flexible fiberoptic intubation was planned. The usual sequence of sedation and topical anesthesia placement was altered in that the transtracheal block was omitted and sedation was reduced. The amount of induration in the neck obscured anatomical landmarks and the risk of hemorrhage or infection was deemed too high for a transtracheal block. After spraying the nose with lidocaine 1.5% phenylephrine 0.25% mixture and placement of cotton-tip applicators with the same mixture, the oropharynx was prepared with a lidocaine 10% spray using metered doses. Satisfactory sedation was achieved with small doses of midazolam, droperidol, and fentanyl. With slight difficulty, the flexible fiberoptic intubation was accomplished and general anesthesia was subsequently induced. Intraoperatively, the floor of the mouth and the visible portions of the tongue became progressively edematous so that no space was noted between the tongue and the hard palate. As a result, an elective tracheostomy was performed with some difficulty. The difficulty arose from preoperative external beam irradiation induced soft tissue changes. After securing the airway with a tracheostomy, the nasotracheal tube was removed and general anesthesia was discontinued. The patient had an uneventful recovery and was decannulated after the plastic tubing was removed and when the edema had dissipated several weeks later. (Fig. 3B and C.)

The edema was secondary to the number of steel needle introducers passed through the soft tissue and plastic tubes that would contain the radioactive implants postoperatively. Additionally, neck fibrosis and trismus were possible as well as tissue breakdown. These factors placed the patient at significant risk for dental damage, hemorrhage, or infection and hence the orotracheal approach was unwise.^{48, 56} Routine topical local anesthetic techniques may need to be altered in these patients. A careful approach to both sedation and topical anesthesia may succeed most of the time. However, even with gentle techniques of maintaining the flexible fiberoptic scope in the midline,⁵⁷ postirradiation changes may make some hemorrhage unavoidable and structures difficult to recognize. Finally, this case illustrates an important point. Despite the relative facility with which flexible fiberoptic nasotracheal intubation took place, a tracheostomy was still needed for postoperative management in order to maintain a patent airway several weeks after radiation therapy.⁵⁶

Case 4

An 18-year-old man with Nager-Reynier syndrome presented for bilateral mandibular advancement osteotomy secondary to severe congenital retrognathia. (Fig. 4). Several previous attempts to perform the procedure were abandoned at other institutions due to the inability to intubate the patient. Nager-Reynier syndrome is a variant of mandibular facial dysostosis (Treacher-Collins syndrome) without the stigmata of colobomata or otologic defects.²² Additionally, the patients with Nager-Reynier syndrome have abnormal digits such as the thumb and great toe. Aside from the presenting syndrome, the patient was otherwise healthy. Pertinent physical examina-



Figure 4. Preoperative view of the patient with Nager-Reynier syndrome.

tion revealed severe retrognathia and digital abnormalities. The patient was able to open his mouth approximately 35 mm of interincisal distance.

The patient was premedicated with the standard midazolam-glycopyrralate preoperatively. Upon arrival in the operating room suite and the application of the routine monitoring sedation and topicalization preceded without difficulty. The attending anesthesiologist attempted the flexible fiberoptic nasotracheal intubation with the endotracheal placed in the nasopharynx prior to placement of the flexible fiberscope. Despite all manipulations with the fiberscope, intubation of the trachea was unsuccessful. The endotracheal tube was then withdrawn completely over the flexible fiberscope and the process was started with the endotracheal tube no longer in situ. Starting with the visualization of the nasal cavity the larynx was seen within 10–15 seconds and then the scope was advanced into the trachea. The nasotracheal tube was advanced without difficulty over the flexible fiberscope. The operation preceded uneventfully after the induction of general anesthesia. Due to the severe retrognathia and the anticipated surgical manipulations, an elective tracheostomy was suggested prior to the termination of general anesthesia and extubation of the trachea. The surgical staff did not think that the mandibular advancement and resultant edema was sufficiently severe to warrant an elective tracheostomy. The patient was transported to the recovery room after surgery. When fully awake and cooperative, the cuff was deflated and the tube was withdrawn into the nasopharynx without fiberoptic guidance. The patient developed airway obstruction within 30 seconds. Despite many airway maneuvers, an emergent surgical airway had to be established. The patient was not decannulated until the fifth postoperative day due to the edema and traction placed on the neck and facial muscles by the antero-displaced advancements of the mandibular segments.

Two judgment errors were made in the management of the patient. The first error was made with respect to the tracheostomy. Despite the ability to avoid a tracheostomy in awake patient by use of the flexible fiberoptic laryngoscope,^{9, 16, 32, 55} it did not necessarily prevent the need for a planned tracheostomy as part of the operative procedure for postoperative management. Frequently, surgically induced anatomical changes and edema compound existing airway difficulties in the head and neck surgical patient.

Early postoperative ambulation and rehabilitation may be impeded by maintenance of the nasotracheal tube in place for several days. The planned tracheostomy as part of the operative procedure after induction of general anesthesia and intubation by flexible fiberoptic laryngoscope will help secure an airway, allow for early rehabilitation and ambulation of the patient. Despite the drawbacks of a tracheostomy, it may be advantageous under these circumstances.

The second judgment error was manifested by extubating a patient with a known difficult airway preoperatively compounded by postoperative surgical changes without fiberoptic assessment. The use of a flexible fiberoptic laryngoscope should have been used to assess the degree of airway edema and anatomical changes as well as its ability to be used as an intubating stylette should any difficulties arise during the extubation process.²⁸ Patients with severe mandibular deformities such as those with mandibulofacial dysostosis should be approached cautiously with the possibility of elective tracheostomy at some time during the operative procedure as well as use the flexible fiberoptic laryngoscope prior to withdrawal of the endotracheal tube.

Case 5

A 32-year-old woman presented for urgent airway management and diagnosis of anterior mediastinal and anterior neck masses. (Fig. 5A). The neck mass progressively enlarged over an 8-week period culminating in dyspnea, dysphagia, orthopnea, and hoarseness. Her past medical history was otherwise unremarkable. Pertinent physical examination revealed an anxious woman who was tachypneic at rest. The anterior neck mass obliterated the suprasternal notch. Breath sounds were clear but diminished bilaterally. The patient's respiratory rate at the time of the examination was 36 per minute with a face mask delivering 40% oxygen and oxygen saturation 93% by pulse oximetry. A plain chest film revealed a widened mediastinum as well as a neck mass and distal tracheal obliteration. Computed tomography (CT) demonstrated that the anterior mediastinal mass compressed the trachea in an anterior posterior direction sufficiently that there was only a 3-mm channel on one side and a 4-mm channel on the other side at its greatest point of compression (Fig. 5B). The mass extended to three centimeters above the carina (Fig. 5C). The glottic inlet was normal (Fig. 5D). It was unclear as to whether the mass merely compressed the trachea or had in fact, invaded the tracheal wall and eroded through the lumen of the trachea. In a multiple disciplinary discussion among anesthesiologists, ENT surgeons, general surgeons, cardiothoracic surgeons and radiologists, many approaches were suggested in the management of this patient. Flexible fiberoptic nasotracheal intubation was suggested with a possibility of transtracheal jet ventilation.⁴ This suggestion was considered unacceptable for several reasons. If the flexible fiberoptic scope had successfully entered one of the two open channels the slightest trauma may create a total obstruction where only partial obstruction had previously existed. Secondly, transtracheal jet ventilation may create undue barotrauma secondary to increased airway resistance and pneumothoraces may have resulted. Finally, if transtracheal jet ventilation was unsuccessful, there

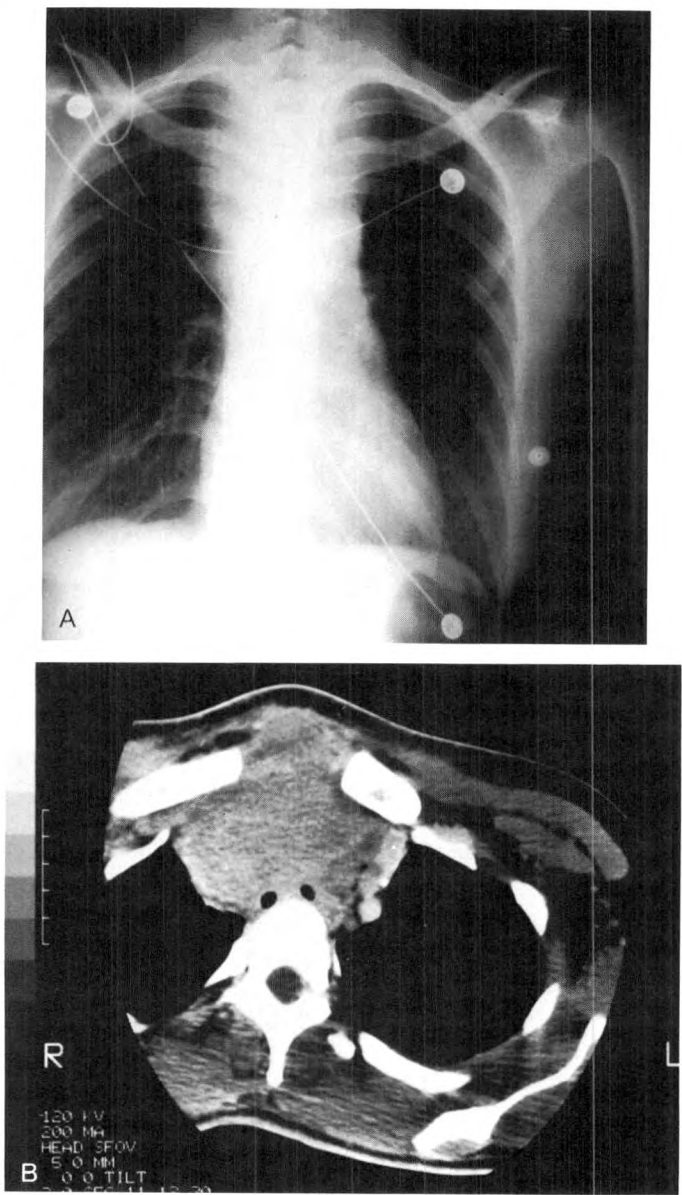


Figure 5. A, AP view of the chest demonstrating mediastinal and neck masses. B, CT view of the midtracheal region with severe anterior-posterior compression and small lateral lumen on each side.

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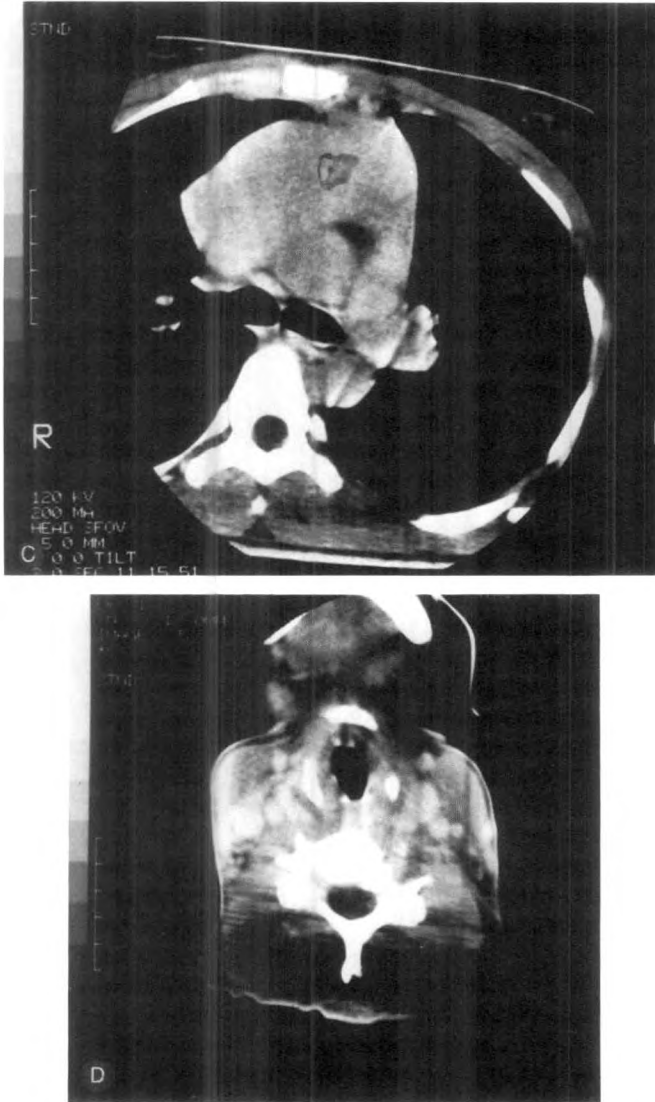


Figure 5 (Continued). C, CT view in the region of the carina demonstrating normal airway caliber. D, CT view in the region of the larynx demonstrating normal airway caliber.

would be no means of ventilating the patient via the flexible fiberoptic laryngoscope. Another suggested approach was to utilize a rigid ventilating bronchoscope alone placed under local anesthesia in the awake patient. However, if the mediastinal mass had eroded through the tracheal wall into the lumen, the risk of tumor dislodgement or severe hemorrhage may also have caused an complete airway obstruction. This suggestion was also considered unacceptable.

The technique that was utilized was the use of the rigid ventilating

bronchoscope after the femoral artery and veins were cannulated under local anesthesia for emergent standby cardiopulmonary bypass. With the femoral vessels cannulated, general anesthesia was induced with thiopental and the rigid ventilating bronchoscope was rapidly and carefully placed by the ENT surgeon beyond the level of tracheal compression to the carina. There was no evidence of tracheal invasion of tumor. Succinylcholine was subsequently administered to facilitate ventilation of the patient. The patient was easily ventilated at this time via the rigid ventilating bronchoscope. There was no evidence of barotrauma. The ENT surgeons then performed a tracheostomy over the ventilating bronchoscope by dividing the neck mass and advancing an uncut endotracheal tube along the side of the rigid bronchoscope. The endotracheal tube was then carefully secured and the ventilating bronchoscope was removed. Finally, the cardiopulmonary bypass cannulae removed from the femoral vessels, general anesthesia was terminated and the patient was transferred to the surgical intensive care unit uneventfully. Biopsy performed at the time of surgery revealed Hodgkin's lymphoma and on the first postoperative day the patient underwent the first of ten days of external beam radiotherapy as well as a course of chemotherapy. The mass had regressed in size significantly so the patient was able to be decannulated on the tenth postoperative day and discharged on the eleventh postoperative day.³⁵

This case illustrates that flexible fiberoptic laryngoscopy and bronchoscopy may not always be applicable to all difficult intubations or airways. Situations where the patient presents with critical tracheal narrowing should be carefully assessed prior to attempting fiberoptic intubations. Mediastinal masses should be preoperatively assessed when possible with computerized actual tomography, flow of volume loops as well as echocardiography.²⁶ Echocardiography will contribute in assessing the degree of cardiac compression by the mediastinal mass. All diagnostic workups and management of the patient should be conducted in the head-up (supine or lateral) position for maximal comfort and gas exchange.⁴³ The fiberoptic scope despite its ability to insufflate oxygen via the suction channel may complete a total airway obstruction in the compromised patient where a partial obstruction initially existed without the ability to ventilate the patient.^{3, 34}

The flexible fiberscope has been advocated for dilating tracheal stenosis,¹¹ or passing the endotracheal tube through a stenotic segment after assessing its depth.⁵³ A skilled endoscopist may experience some difficulty and create some mild trauma at the levels of the stenotic segment thus increasing resistance to airflow or totally obstructing the airway despite the availability of even the smaller pediatric fiberscope.³ Earlier reports suggested that awake tracheostomy prior to en bloc resection of laryngeal cancers would increase the likelihood of stomal recurrence of the cancer. Hence, flexible fiberoptic intubation was suggested to prevent this occurrence despite a critically narrowed glottis or tracheal lumen.⁵⁴ However, the usual safety considerations as well as recent retrospective multivariate analysis demonstrated that stomal recurrence is most commonly related to subglottic cancer preoperatively rather than preoperative tracheostomy.³⁷ The approach at Eye & Ear Hospital of Pittsburgh is to perform an awake controlled tracheostomy in the patient with a critically narrowed airway

rather than risk total airway obstruction with attempted flexible fiberoptic laryngoscopy. Inflammatory or infectious processes such as epiglottitis should be regarded in a similar manner.¹⁰

SUMMARY

The flexible fiberoptic laryngoscope is a significant and necessary adjunct in the management of the difficult airway and intubation in the head and neck operating room suite. The anesthesiologist should master the use of this device in order to skillfully manage the head and neck patient. Flexible fiberoptic laryngoscopy greatly aids in the diagnosis of problems, the identification of normal and abnormal anatomical structures, and as a visual intubating stylette. It is a device that turns corners which may be obscured from plain view due to anatomical derangements. However, flexible fiberoptic laryngoscopy and subsequent intubation should never preclude nor be a substitute for the rational need of a tracheostomy. Fiberoptic endoscopy must be carefully selected and appropriately utilized since the scope itself may become part of the airway problem.

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Address reprint requests to

Andrew Herlich, DMD, MD
Department of Anesthesiology
230 Lothrop Street,
Pittsburgh, PA 15213

Fiberoptic Endoscopy and Anesthesia in a General Hospital

*Charles B. Watson, MD**

The practice of anesthesia is procedure oriented and, although anesthesiologists differ in so far as their comfort with specific regional techniques or anesthetic sequences, the one procedural area that we feel a common, proprietary sense of exclusive expertise in is airway management. Among other medical colleagues we are accepted as having a unique, daily acquaintance with the airway rivaled by very few. Among ourselves, one of the worst criticisms that can be offered is that of airway mismanagement. It is precisely because of this hard-won expertise in airway management that we are so facile with sedated, obtunded, and anesthetized patients. It is also because of this that most of us are devastated by the airway that defeats us—the trachea that we cannot intubate. Indeed, some deny ever having encountered such a problem although it seems most unlikely and either due to selective memory suppression or to inexperience.

Given the importance we ascribe to airway management and tracheal intubation, it is not surprising that innovative technical aids are frequently introduced. As with most technical modifications, some help the innovator and his colleagues and, thus, survive the test of time. Others pass away because, with experience, they don't live up to the promise of increased convenience or a higher success rate. For example, most modifications of the laryngoscope blade are not so widely used as the Miller and Mac, and Magill forceps are widely used while an assortment of ingenious tube benders and guided stylettes are not.

Over the years a number of fiberoptic tools have been offered to the anesthesiologist that promised aid in airway management. Putative advantages are flexibility, a brighter light, magnification, atraumatic visualization, and a deeper view of the airway. Instruments include the flexible laryngoscope, the malleable and rigid fiberoptic stylettes, the Bullard Laryngoscope, the Hopkins telescope, and a broad spectrum of flexible fiberoptic bronchoscopes. Will any of these survive the test of time and clinical experience? Will they become as commonplace in our practice as, say, the pulmonary

*Chairman, Department of Anesthesiology, Bridgeport Hospital, Bridgeport, Connecticut

artery (PA) catheter or the epidural catheter? Or will they be relegated to the obscurity of the rarely needed or overly complex?

Experienced practitioners for whom I and others have given fiberoptic lectures or workshops often ask—Is it worth the trouble? For some, given the high success rate of tracheal intubation and the other options available (e.g., mask airway, surgical tracheostomy, or regional techniques) the response has been cautious skepticism. Others identify the need for something else only when they have an acute problem—failure to intubate. Many have adopted a “wait and see” attitude. This is not unexpected since fiberoptic equipment, as familiar to us as it is from intraoperative bronchoscopy, requires a new set of skills of the user and a significant commitment for purchase, maintenance, and repair.

I and others have long maintained that the versatility of a fiberoptic bronchoscope justifies the effort required for mastering it.¹² One of our problems with the technology has been that efforts to create a more anesthetist-friendly device have failed. The flexible laryngoscope was cheap and useful but it had poor light, inadequate or no suction, inferior optics and too large an external diameter. Optical styletettes, although offered in a malleable format as well as with a rigid curve, can not be redirected with ease, have a large external diameter, and do not have suction. The Hopkins telescope, despite its magnification and superior optics, can not bend around corners and offers only marginal improvement upon the flexible fiberoptic laryngoscope or a rigid fiberoptic blade. The Bullard laryngoscope is, essentially, a bent Hopkins telescope shaped as an oral airway with a manipulator channel—if the angle isn’t appropriate for the patient only the lucky will successfully prevail. The full length flexible fiberoptic bronchoscope offers the user a versatile approach to abnormal anatomy and management of both upper and lower airway intubation problems.

So much for the academic arguments. What about those busy individuals in private practice who rarely see bizarre problems and have difficulty obtaining the money, recruiting the assistance, and devoting the time needed for fiberoptic techniques? The clinical anesthetist is learning how to use the instruments in numerous workshops, in basic training, and through the medium of numerous review articles, text chapters, and at least two lengthy monographs on the subject. I offer the following cases as examples from clinical practice that illustrate the utility of endoscopic techniques. I can not claim that a majority of anesthesia colleagues at my community hospital have taken the time to learn, but interest is growing and the technique is catching on. Roughly a third of my group uses the flexible fiberoptic intubating bronchoscope (FFB) for confirmation of double-lumen tube placement and the occasional intubation. Our surgeons and medical colleagues consult us with this in mind and I am persuaded that they shall continue to do so. Twenty years have passed since the case reports were first published. Fiberoptic techniques are here to stay.

UPPER AIRWAY PROBLEMS

Obese Patient with a Difficult Airway

Problem. The Anesthesia Department was asked to evaluate a 63-year-old woman requiring mastectomy for cancer whose previous anesthetic was

complicated by a cardiac arrest because of an "airway problem." The patient's fear of anesthesia was so great that the surgeon, who ordinarily performs breast biopsies under local anesthesia with monitored anesthesia care, had performed the biopsy under "local local" a week previously.

The Presentation. The anesthesiologist met a hostile patient who expressed great fear on the basis of her experience at a neighboring hospital 5 years previously during dilation and curettage (D & C). She stated that her heart had stopped briefly because the anesthetist couldn't ventilate her and that her upper incisors were knocked out during intubation attempts. Afterwards she had had expensive bridge work performed. After seriously considering legal action against the anesthesiologist involved, she had resolved to avoid anesthesia again.

The history and review of systems were remarkable for many positive answers (dizziness, blurring vision, orthopnea, dyspnea on exertion, snoring, chest pain, ankle swelling, loose teeth, abdominal discomfort after eating, aching joints, stiff neck, occasional wheezing with colds, and allergies to anesthetics and pain medicines) but no significant sicknesses in recent years except for hypertension and breast cancer. The patient had stopped smoking 10 years previously, only drank alcohol socially, and was taking no medicines. She had been widowed for 6 years.

Review of the chart and other consultant's notes confirmed the impression of mild hypertension and multiple complaints. No significant cardiac disease had been revealed upon examination by an internist and cardiologist. The electrocardiogram (ECG), echocardiogram, stress test and thallium scans were negative and consistent with mild hypertensive cardiomyopathy and no coronary or valvular heart disease. Hypoxemia on room air (sitting $\text{PaO}_2 = 82$ mm Hg.) and a mild restrictive defect were noted upon pulmonary function testing. Laboratory data suggested normal renal, hepatic, and thyroid function. A phone call to the neighboring institution was unfruitful: no one could remember the patient and the chart could not be located.

Physical examination revealed an obese (5'2", 192 lb) white female with a short, thick neck. Both nares were unobstructed. The neck moved normally, but only the anterior aspect of the tongue and hard palate could be seen with mouth opening to an interdental space of three fingerbreadths. A fixed bridge was present replacing central and left upper incisors and the right second upper incisor and bicuspid teeth were noted to be loose and carious at the gingival margin. Lungs were clear although breath and heart sounds seemed distant. All pulses were intact and no bruits were noted. Diastolic hypertension (90–95 mm Hg) was noted in supine and sitting positions. The patient was not comfortable supine although respiratory distress was not noted. Mild dyspnea was noted when getting up to walk down the hall; the dyspnea did not interfere with conversation.

Plan. Discussion with the patient proposed airway control prior to the induction of general anesthesia with nasal or oral intubation. The patient expressed great anxiety and stated that she wished to be put to sleep and to know nothing about her anesthesia and surgical care. She was resigned to all risk, including emergency tracheostomy and death, but refused to accept awake instrumentation. She would, reluctantly, accept sedation and

anything we wished provided that she could be reassured of feeling and remembering nothing uncomfortable. Sedation with amnesic and analgesic medication, oxygen administration, and fiberoptic intubation nasally or orally were described as first choices. Tracheostomy and intensive care unit (ICU) admission were documented as possible and, although the patient disliked this concept, awake extubation in the post anesthetic care unit (PACU) if all went well was planned.

Course. The patient was premedicated with oral diazepam. She was brought to the Operating Room where an intravenous (IV) and monitors, including ECG, oscillometric noninvasive blood pressure system (NIBP), and precordial stethoscope were applied in the sitting position. Nasal oxygen was administered. Increments of midazolam ($\frac{1}{2}$ mg) and fentanyl (25 μ g) were given as topical anesthesia of the nares was achieved with cocaine hydrochloride (2 cc, 4% solution) and cotton-tipped applicators while the surgeon stood by in preparation for urgent tracheostomy as necessary. The SaO_2 ranged from 90 to 96%. When snoring was noted, obstruction and desaturation were easily resolved with gentle anterior traction on the jaw. An FFB was inserted and advanced through the right naris after it could be demonstrated that movement of four cotton-tipped applicators together in an anterior-posterior direction caused no response. A total of 3 mg of midazolam and 2 cc fentanyl were given. As the FFB was advanced from nasopharynx through posterior pharynx to visualize the larynx, very little space between the base of tongue/epiglottis and posterior pharyngeal wall was evident without traction on the mandible by an assistant. The patient was sitting at 60° with the assistant monitoring her from behind the head and the endoscopist in front, facing the patient. The cords were visualized and sprayed with 2 cc, 2% lidocaine via the suction channel of the FFB. At this time the patient coughed and the FFB was withdrawn. The FFB was then threaded through a ventilating adaptor (Portex, Wilmington, MA) attached to a lubricated 6.5 mm tracheal tube (Mallinckrodt, Glens Falls, New York) and the 15 mm adaptor of the circle system on an NA Dräger 3 anesthesia machine. As oxygen was insufflated, the FFB was again inserted to the level of the larynx and advanced below the vocal cords to the mid-trachea as care was taken to avoid contact with the tracheal walls. The tracheal tube was advanced *via* the naris over the FFB through the larynx and into the trachea with the insertion cord of the instrument held under counter traction and a slight twisting motion of the tube. At this point, the patient coughed and moved her head. When the tip of the FFB was within the tube and above the tracheal carina, the cuff was inflated and the instrument withdrawn as the tube was held by the operator and 125 mg of sodium thiopental were administered by the assistant. An anesthetic gas mixture consisting of 40% oxygen in nitrous oxide with 2% isoflurane was given as the patient was positioned for surgery. The blood pressure rose to 180/100 mm Hg and the heart rate to 88 bpm during coughing but became more stable with induction of anesthesia.

Outcome. At the end of the procedure the patient was taken to the PACU with endotracheal tube in place and extubated when more awake and responsive. She had no unpleasant recall and was given low flow

oxygen after extubation by nasal cannulae. Her teeth were intact before transfer from the PACU. She was sent to her room on the ward 2 hours postoperatively with a stable SaO_2 of 96% on 2 liters nasal oxygen.

Follow-up. When visited two days postoperatively the patient did not recall perioperative events but noted that a missing tooth had come out on the first morning postoperatively. This was not documented in the nursing notes but a nurse had suggested to the patient that perhaps the anesthesiologist had loosened the tooth in the operating room. At this time the events of surgery and perianesthetic care were reviewed with the patient in detail and briefly summarized in the progress notes of the chart. The incident was referred to the anesthesia department's Q/A committee, the hospital's risk manager and the anesthesiologist's malpractice carrier. As the patient was discharged later that week, she expressed satisfaction with her care and that she had no desire to sue anyone. She was given a summary letter by the anesthesiologist that documented her past problems, together with her most recent anesthetic, and suggested awake, sedated intubation or regional anesthesia as safe alternatives in the future.

Discussion. This would be a difficult case no matter what anesthesia was planned. Given her history and perception of problems associated with anesthesia, some practitioners would have referred her to another center in order to avoid obligation to a difficult patient who seemed to be destined to experience some type of anesthetic complication. Airway management options were limited by the patient's insistence upon amnesia for all events and hampered by lack of an adequate history. The anesthetist who takes a patient like this on without documentation of physical assessment and anesthetic management options together with some act of informed consent will be fortunate, indeed, if he can avoid a major risk management problem.

Management options include "awake," sedated, blind, nasal or oral techniques, direct oral techniques and cricothyrotomy or tracheostomy. A commonly proposed alternative to "awake" intubation, rapid-sequence induction with short-acting agents, assumes that the patient has an adequate oxygen storage reserve to uptake ratio (FRC/consumption) and that the anesthetist can manage the airway during emergence should intubation efforts fail. One should think twice before inducing general anesthesia without a secure airway, given the history of arrest under anesthesia for a brief case like a D & C. In this case, the patient's concern regarding her teeth and her obvious dental problems suggested that any oral approach should be avoided, if possible. Blind techniques were avoided since it was felt that bleeding and trauma in this patient could make further fiberoptic or other direct visualization approaches impossible. The very real concern for loss of airway due to overenthusiastic sedation was approached by carefully titrating sedative and narcotic drugs and planning tracheostomy from the start should less invasive efforts fail.

Technically, fiberoptic intubation of obese patients is more difficult. While the larynx generally is easily seen by a flexible instrument as it passes behind the palate, increased fatty tissue and poor respiratory muscle tone narrow the pharyngeal airway and often make the approach behind the epiglottis require more manipulation of the FFB before the larynx can be seen. The pharyngeal airway is better maintained in the sitting position

(as is FRC). Awake patients are both more comfortable and less likely to panic when sitting. Swallowing function is also better maintained; secretions do not pool at the level of the hypopharynx and glottis. Often anterior traction on the mandible will help, as it did in this case, and occasionally manual retraction of the tongue is the only maneuver that will bring the larynx into view. Some endoscopists routinely insufflate oxygen through the suction channel of the instrument because it tends to distend pharyngeal tissues, defog the objective lens on the working tip, and provides a direct oxygen source for the patient in case sedation or coughing promotes hypoventilation. Cooperative patients who are awake can pant, phonate, open their mouths and protrude their tongues as requested by the endoscopist—all maneuvers that elevate the base of the tongue and the epiglottis so that the larynx is more readily viewed. Topical anesthesia of the larynx is greatly assisted by the antitussive effects of narcotics. Although I prefer the “spray as you go” technique for laryngotracheal anesthesia, one can perform superior laryngeal nerve blocks or transtracheal injections with low morbidity. When one is using a small endoscope, smaller than normal tracheal tubes are more likely to pass easily over the instrument through the naris and the larynx. The tube is advanced with a gentle twisting motion as counter traction is held upon the insertion cord of the intubating endoscope so that the tip of the tube will not catch on the cords and “hang up” during passage. After intubation, it is wise to ascertain that the tracheal tube is, indeed, within the trachea before administering intravenous anesthetics or relaxants since smaller endoscopes are more flexible and can slip out of the trachea as the stiffer tracheal tube catches during passage.

The outcome was satisfactory. If appropriate follow-up had not identified tooth loss and allowed a reiteration of the events, the patient might have had the notion that the anesthetist knocked her tooth out reinforced by other, well-meaning personnel. Also, since patients notoriously forget the most part of what they are told, a written note for the next anesthetist or any other physician or dentist who might need to know provided a personal record for her benefit.

Conclusion. Although other techniques might have managed this patient who needed mastectomy for cancer, the FFB presented some advantages. The airway was minimally obstructed and instrumented as its anatomy was directly visualized with no airway or dental trauma. Oxygen and local anesthetic can be instilled through the endoscope as it is advanced, thus obviating the need for direct injections or another airway.

Child with a Fixed Mandible and Neuromuscular Disease

Presentation. The anesthesia consultation service was asked to see an 11-year-old with neuromuscular disease whose frozen temporomandibular joints did not allow her to eat properly. The child came into the hospital in an electric wheel chair when scheduled for pre-admission testing.

The Problem. The anesthesiologist found an outgoing girl who appeared weak, relying on her chair for support, and who spoke without opening her mouth very far. She said that she had walked when she was much younger but that she had had to use the wheel chair for several years and that she had difficulty holding her head up. Her parents stated that she had an

unknown degenerative nerve problem that prevented her from sitting without assistance. She was seen monthly in a neighboring teaching hospital where it was noted that she had no cardiac or pulmonary disease. Old records from this source documented the fact that her limitation was entirely due to weakness. Joint instability and immobility had led to flexion contractures of the knees and elbows. The entity was identified as a degenerative leukodystrophy. The child's most recent weight was recorded as 46 lbs. The oral surgeon's consultation documented progressive temporomandibular joint (TMJ) entrapment of unknown etiology. The child and her parents were eager to have the surgery so that she could open her mouth and eat normally.

Physical exam revealed an alert, weak girl who balanced her head on her neck with difficulty and tended to lean upon the chair for support. Eye movements were normal and she was bright and alert. Her voice was weak although speech was clear. Mouth opening was limited to one finger breadth. She could protrude her tongue and move it from side to side on command. The gag and cough reflexes were intact, but cough appeared weak. Accessory muscles of respiration were seen to be in use. The heart and lungs were normal to exam and pulses full and intact. Flexion contractures limited arm and knee extension to approximately 140°. Deep tendon reflexes were intact at pectoral, biceps, and quadriceps levels. Poor muscle development was noted to be symmetrical. An arterial blood gas on room air was normal in the sitting position and the child could blow out a match held one foot from her mouth only if she pursed her lips. Complete blood count (CBC), electrolytes, liver functions, blood urea nitrogen (BUN), glucose, and creatinine were normal as were the ECG and chest films.

Plan. The preanesthetic discussion emphasized the problems of weakness and the need to secure an airway as atraumatically as possible. The child was shown a pediatric fiberoptic bronchoscope (3.7 mm diameter) and the method of providing topical anesthesia to the nares and pharynx demonstrated with lidocaine spray (Hurricane, metered 10% solution) applied to the tip of the tongue. Awake, monitored fiberoptic intubation followed by inhalation anesthesia with halothane and oxygen in nitrous oxide were planned. The possibility of postoperative respiratory failure and need for continuous mechanical ventilation were presented and accepted by the child and her family.

Course. On the morning of surgery the patient was admitted to the hospital and brought to the holding area where the anesthesia team that had performed consultation met her and, after reassurance, started an intravenous infusion of dextrose and half normal saline. Two 15- μ g increments of fentanyl citrate were administered IV and she was taken to the operating room on a stretcher with the head elevated to 60°. ECG, pulse oximeter, noninvasive blood pressure (NIBP), and precordial stethoscope were applied. The right naris was sprayed twice with 10% lidocaine. Cotton tipped applicators were used to topically anesthetize the mucosa with 0.75 cc, 4% cocaine hydrochloride. An intubating FFB (Olympus, Lake Success, New York, LF-1) carrying a cuffed 5.5 tracheal tube was advanced into the pharynx and the epiglottis and larynx were immediately visualized. Cord motion was noted to be normal with speech and inspiration. Glottic closure

upon swallowing was normal. Two aliquots of 1% lidocaine solution were injected through the suction channel of the instrument as the patient was instructed to inhale. The endoscope was advanced into the trachea as the child panted and an additional lidocaine dose administered, after which the FFB was withdrawn until coughing subsided. The tracheal tube was then advanced gently into the posterior pharynx and the FFB passed again into the trachea to a position just above the carina. The child was instructed to inhale deeply as the tracheal tube was passed into the trachea. The FFB was withdrawn and 50% oxygen in nitrous oxide administered with 1% halothane as 50 mg of sodium thiopental were administered. She was positioned for surgery. The tracheal tube was taped after the FFB was quickly passed again to verify the position of the tube tip 2 cm above the carina. The intubation process took 15 minutes from entrance into the operating room until positioning for surgery. Surgery lasted for approximately one hour after which the girl was taken to the recovery room. She was extubated uneventfully in the sitting position an hour later after demonstrating a forced vital capacity of 400 cc, a tidal volume of 150 cc, head balance no worse than control, and normal blood gasses.

Follow-up. The child was able to take soft foods by mouth and to drink later that evening. She was observed overnight in the hospital and discharged the next afternoon. She reported that the awake intubation had not been unpleasant although she was frightened when she could no longer talk and she was happy to be extubated.

Discussion. Tracheal intubation was preferred by the surgical team in this case so that they could confirm mandibular motion and directly place their hands in the mouth during and after the procedure. There were three indications for awake intubation. First, a fixed jaw required nasal intubation to prevent loss of the airway. Second, limited neuromuscular reserve suggested that heavy sedation or inhalation anesthesia might be poorly tolerated unless ventilation were controlled. Third, laryngeal dysfunction might require long-term intubation and it would be reassuring to assess baseline protective airway reflexes under direct vision prior to anesthesia. Two alternatives are commonly employed in children: blind or fiberoptic intubation under ketamine anesthesia or inhalational anesthesia. Both are likely to succeed if the larynx and airway are normal in location and function. Neither leaves much alternative to surgical access to the trachea when the airway is lost or unmanageable. This highly motivated child could understand the problem involved and was willing to participate in her own care. Sedation with an antitussive agent, progressive topical anesthesia and good patient rapport made this technique successful. The information provided by direct examination of the larynx reassured the anesthesia team that extubation would be safe, provided that neuromuscular function was adequate and no residual anesthetic drugs were evident. Avoidance of muscle relaxants—both depolarizing and non-depolarizing—allowed a more simple approach to assessment of neuromuscular reserve post operatively and avoided the issue of mass reflex or hyperkalemia following succinylcholine.

Conclusion. With appropriate preoperative assessment and counseling, awake fiberoptic intubation was expeditious, atraumatic, and safe in this

unfortunate little girl. Alternative approaches were possible; however, useful information was obtained at endoscopy that assisted with the decision to extubate her.

Trauma Patient in Cervical Traction

Presentation. A 20-year-old man was brought to the emergency department following a motor vehicle accident with neck pain, a broken right arm, multiple facial and chest lacerations, and obvious alcohol intoxication. Lateral neck films revealed C5–7 fractures with bone fragments near the cervical cord. The patient was placed in cervical traction, the arm was casted, and he was monitored in the intensive care unit for signs of other injury or neurologic progression from alcohol detoxification. He was scheduled for emergent posterior cervical decompression when neurologic evidence of cord compression was noted.

The Problem. The anesthesiologist met a coherent young male who noted pain in his neck and arm and had freshly sutured facial lacerations. The patient was in cervical tongs with 20 pounds of traction and complained of pain with any neck motion or palpation of the neck posteriorly. Laboratory values, ECG, and chest radiograph were unremarkable and the patient had been hemodynamically stable for 12 hours. Tox screen revealed a blood alcohol level of 185 mg/dL. Urine was negative for cocaine, barbiturates, PCP, and narcotic metabolites. The neurosurgeon asked the anesthesiologist to be particularly careful during intubation because he felt the neck to be unstable. Loss of sensation in the lower extremities had been documented together with weakness during the past two hours in the ICU. The patient could clear his throat, swallow, and demonstrated effective spontaneous coughing. Because of facial lacerations, he preferred not to open his mouth. Two teeth were missing from the mandible and bloody saliva was noted. Radiologic views of the facial bones and sinuses demonstrated a mandibular fracture. A radial arterial and two peripheral venous catheters were placed in the preoperative period. A urinary catheter drained clear, yellow urine.

Plan. Awake, sedated fiberoptic nasotracheal intubation was discussed with the patient and his family. The risk of spinal cord injury with neck movement during intubation or surgical positioning was covered in detail and “awake” pronation was identified as a way of monitoring neuromuscular function throughout this period. The neurosurgeon was enlisted to aid in this process by providing traction during positioning and monitoring traction and neurologic function during tracheal intubation. General anesthesia with a fentanyl, midazolam induction followed by nitrous oxide and enflurane in oxygen with paralysis was planned. Nasotracheal intubation in the postoperative period was anticipated pending demonstration of stable neurologic and respiratory function in an external fixation device.

Course. The patient was brought to the neurosurgical operating room where pulse oximeter and ECG monitors were applied. He was sedated with increments of fentanyl and midazolam intravenously as oxygen was administered by nasal cannulae. When it was possible to insert cotton-tipped applicators into the nasopharynx with comfort, cocaine hydrochloride, 2 cc of 4% solution were applied to each naris respectively. The right naris was then suctioned and a lubricated 28 French soft nasopharyngeal

airway was passed. The oropharynx was sprayed with three metered doses of 10% topical lidocaine and secretions suctioned from the patient's pharynx via the nasal airway. A 4 mm intubating FFB (Olympus, LF-1) was passed through the right naris after removal of the nasopharyngeal airway. After passing behind the palate, the larynx was viewed from the posterior nasopharynx. The endoscope was advanced to a level just above the vocal apparatus and 2 cc of 2% lidocaine were injected during inspiration. The instrument was withdrawn and the patient spontaneously coughed once and was asked to bring secretions up to the front of his mouth where they could be suctioned. The FFB was reinserted, carrying a 7.5 mm cuffed tracheal tube attached to a ventilating adaptor that was connected to the circle system of the anesthesia machine flowing 8 liters of oxygen. As the patient panted, the FFB was advanced to a position below the cords and an additional 2 cc of 2% lidocaine were injected through the suction port. A brief cough was noted and the patient indicated that he was comfortable breathing slowly. With the carina in view, the tracheal tube was advanced through the naris and, then, through the larynx over the FFB as the patient was instructed to concentrate on breathing through his nose slowly. The FFB confirmed the tracheal tube's position and was withdrawn. Afterwards the cuff was inflated and tube secured to the upper lip and nose. Additional fentanyl was given as the patient breathed quietly through the tracheal tube and a foam cushion was applied to the face and forehead. After this, the traction weights were removed and traction was maintained by the neurosurgeon as the patient was assisted in rolling to the operating room table following commands. His arms and legs were padded and his head maintained in neutral position as the weight was reapplied. He was able to assist in placing knees and arms and in moving his torso into the proper position on the laminectomy frame. At this time additional midazolam was administered and, as he became apneic, the patient was paralyzed with pancuronium bromide and ventilated with enflurane and 60% nitrous oxide in oxygen. The surgical prep was begun approximately 30 minutes after entry into the operating room.

Outcome. After decompression, the patient was turned onto an ICU bed with a padded plastic and metal jacket shell under his back. Traction on the head was maintained as halo spikes were inserted and the anterior and posterior portions of a Minerva jacket secured to the halo. He was taken to the ICU where he was ventilated on low rate intermittent mandatory ventilation (IMV) for several hours and weaned to continuous positive airway pressure (CPAP). After demonstrating a stable neurologic picture for 12 hours, he was extubated. He was pleased to be able to talk and had no unpleasant recall of the intubation/positioning process. He was returned to the operating room on a later date when open reduction, internal fixation (ORIF) of his arm fracture was completed under axillary block anesthesia without difficulty. Facial lacerations healed well and the patient was able to take liquids and, then, a soft diet within a few days. His jaw fracture did not require fixation. After three weeks he was transferred to another facility for long-term convalescent care.

Discussion. It is not uncommon to encounter blunt trauma patients with proven or suspected neck injury in community practice. If the setting

is one of acute respiratory or cardiovascular decompensation, insertion of an airway is paramount. When more time is available tracheal intubation for secretion management or surgical intervention must be performed with close attention paid to head and neck position. Many anesthesiologists perform direct laryngoscopy as traction is applied by an assistant or the neurosurgeon. Some perform "awake" nasal or oral intubation while others prefer intubation under anesthesia. In this case, both the anesthesiologist and the neurosurgeon felt most comfortable with a technique of "awake" intubation and positioning that would allow the least risk of airway trauma, a staged approach to topical anesthesia of the airway, and direct documentation that neurologic function was unchanged prior to surgical decompression. No one could argue that this logical approach is the "standard of care". Some might argue that spontaneous coughing of a poorly controlled patient could pith him before surgery. In view of the pain during movement of this patient's jaw, either intubation under general anesthesia or blind, "awake", sedated nasal intubation or tracheostomy are other choices. Coughing can also occur with a blind nasal intubation. In fact, the risk of nosebleed, trauma to the larynx, coughing, and failed intubation is greater since the tracheal tube can not be visually directed into the trachea. The FFB is, in effect, a stylette that has been atraumatically placed. Awake tracheostomy would not ensure a stable neck either. It is also more difficult to position a patient prone for neck surgery with a tracheostomy.

Conclusion. In this case, judicious use of sedative/narcotic agents and topical anesthesia together with good patient rapport and a neurosurgical/anesthesia consensus culminated in a happy outcome. The patient moved no more than he had prior to surgery and it was possible to document satisfactory neurologic function after intubation and patient positioning. The time involved was not inordinate for the surgical set-up involved. All of the parties involved—anesthesiologist, patient and neurosurgeon—were pleased with the process. Awake, sedated, fiberoptic intubation offers a satisfactory approach to the care of patients with unstable neck fracture in traction.

Eleven Year Old with a Retropharyngeal Mass

Problem. An otolaryngologist scheduled emergency endoscopy and surgical decompression of posterior and lateral pharyngeal mass in a febrile 11-year-old boy. The child had had a six day course of sore throat that progressed to dysphagia and noisy breathing. The surgeon cautioned the anesthesiologist on call that the larynx was deviated. Suspecting an abscess, he specifically requested that the mass not be compressed during laryngoscopy, if possible.

Presentation. The boy and his family were interviewed in the Emergency Department. An intravenous catheter had been placed and antibiotic infusion begun. The boy was sitting upright, his color was good, and his breathing noisy but unlabored. His parents stated that he wouldn't eat breakfast or lunch and, when he refused to drink or take his antibiotic pills at dinner time they brought him to the hospital. The child's medical history, family history, systems review and physical exam were unremarkable except for the chief complaint. His parents said that he weighed 72 lbs when last

checked a few months ago. He was tachycardiac to 125 bpm, febrile to 102°C. and had a respiratory rate of 32. Lungs were clear but noisy upper airway sounds were noted in inspiration and expiration. Stridor was not appreciated. The odor of the breath was foul. The boy could speak but said that it was uncomfortable and spoke in a choked voice. He refused to swallow. The neck was grossly swollen above and at the level of the larynx while the larynx was displaced to the left. Anterior-posterior and lateral neck films revealed tracheal deviation to the left at the laryngeal level and narrowing of the pharyngeal air column with an increased thickness of the retropharyngeal soft tissues. The thoracic airway column was normal on chest radiograph and no "steeples" sign or blunting of the epiglottis was noted although it could not be clearly seen.

Plan. Special emphasis was placed upon the problem of the airway in discussions with this child's family. The importance of tracheal intubation as a means of protecting the lungs from drainage of pus and blood led to the question of how it could be achieved without causing pain. Possible problems with intubation "awake" and sedated *vs* under general anesthesia were discussed. The anesthesiologist recommended FFB intubation with sedation or direct laryngoscopy under anesthesia, depending upon the findings at endoscopy. The boy was shown a pediatric FFB and told about how it worked. He was promised that, if it was comfortable, he would be shown his own voice box as he talked and breathed. He and his family agreed to fiberoptic laryngoscopy and the placement of a nasotracheal tube over the instrument if it were not too uncomfortable. Alternate plans failing atraumatic intubation attempts included surgical tracheostomy under anesthesia.

Course. After small doses of intravenous fentanyl and a spray of the nostrils with 10% lidocaine in the parent's presence, the boy was taken to the Operating Room and placed in a semi-Fowler position. Pulse oximeter, NIBP, ECG and stethoscope were applied and oxygen given by nasal cannulae. Increments of fentanyl citrate up to 2 cc were given intravenously as the left naris was, in turn, sprayed with 10% lidocaine and topically anesthetized with 0.75 cc cocaine hydrochloride. A 3.7 mm pediatric FFB (Olympus C3-4) was advanced into the retropharynx. The boy was asked to open and to breathe through his mouth because the pharyngeal airway was narrowed, even in the sitting position. The epiglottis was seen to be tilted to the left and laterally deviated. He was shown his epiglottis and asked to phonate while watching through the FFB. The FFB was manipulated to a position behind the larynx after two sprays of 2 cc of 2% lidocaine that loosened thick secretions were suctioned. The boy was again shown the view through the endoscope and it was withdrawn.

After an additional cc of fentanyl, the boy had a respiratory rate of 12/min. and would fall asleep unless aroused. The instrument was withdrawn, the tip cleared of secretions and the insertion cord passed through a cuffed 5 mm endotracheal tube with ventilating adaptor. It was then passed to a position just above the larynx as gentle anterior traction was applied to the mandible by an assistant. The larynx was sprayed a second time with lidocaine as the boy was instructed to breathe in. He coughed and then breathed regularly through his mouth as the FFB was passed into the

trachea. Then the tracheal tube was inserted over the FFB and, after prompt inflation of the cuff and verification of tube location within the trachea by the FFB, 125 mg thiopental were administered intravenously as the boy coughed on the tracheal tube. He was further anesthetized with halothane 2.5% in nitrous oxide 70% and oxygen as he was positioned for upper airway endoscopy and the tracheal tube was secured. A large abscess was drained that was noted to extend posteriorly into the prevertebral fascia from the lateral neck and anteromedially towards the larynx and base of the tongue.

Outcome. The boy was taken to the Pediatric ICU with nasotracheal tube in place and placed on CPAP. By the next morning he was extubated by the anesthesiologist over a FFB. Laryngeal function and swallowing were noted to be normal. He defervesced under therapy with intravenous antibiotics. He denied unpleasant recall and stated that he enjoyed seeing his voice box through the FFB. The abscess culture yielded a mixed culture of staphylococcus, streptococcus, and *Neisseria catarrhalis*.

Discussion. Children and teenagers can be endoscoped and intubated awake if approached in a methodical, gentle fashion. A 5-ID endotracheal tube is the smallest that should be passed over a 3.7–4 mm bronchoscope. Oxygen insufflation during the procedure is well advised whether a child is sedated or crying since transient breath holding or laryngospasm can lead to rapid oxygen desaturation. When he is able to understand the procedures involved, the child's assistance can be enlisted and the medical procedure can become an interesting adventure. As with many pediatric procedures, early involvement of the parents in the process serves to establish better rapport and to reinforce the notion that intubation need not be frightening for the child.

Although most anesthetists would have elected to intubate this child under deep inhalation anesthesia or as part of a rapid sequence induction technique, the abnormal position of the larynx suggested to both the anesthesiologist and the otolaryngologist that direct laryngoscopy might be more difficult than usual. Indeed, rupture of a pharyngeal abscess during laryngoscopy might complicate the picture further by contributing to aspiration pneumonia or, worse, an acute aspiration syndrome. Since the abscess extended to the base of the tongue and deviated the larynx, it is most likely that intubation under direct vision from the right side would have been difficult. In such cases, laryngoscopy from the left side of the tongue using a straight blade with cephalad counter-pressure on the cricoid is often helpful. Pressure exerted on a left-sided abscess would be greater using such a technique. In any event, one must recognize that the apnea time of an infected, hypermetabolic child is likely to be much shorter than that of the average preoxygenated adult and monitor oxygenation as well as limit the duration of apneic laryngoscopy.

Conclusion. A child can be intubated awake if appropriate preparation, a staged approach towards more invasive interventions, and gentle treatment builds a bond of trust between the anesthetist and the child. This child had a potentially life-threatening problem that was resolved before the induction of anesthesia. In the event the child was unmanageable, other alternatives were available, including tracheostomy, and the parents

most likely had greater respect for the anesthesia and surgical team because of the special attention and planning revealed in formulation of the anesthesia plan.

Neck Contracture and Microstomia following Burn

Presentation. The director of the burn unit consulted the anesthesia department for surgical debridement of a 7-year-old black girl who had recovered from face, neck and truncal burns sustained in a house fire 18 months previously. He stated that the neck was so contracted that he could not do a tracheostomy, but proposed a rapid scar release under mask anesthesia if tracheal intubation were unsuccessful.

The Problem. Anesthesia consultation was performed in the Outpatient Testing Area. The child, aside from the trauma of severe, deforming burns and prolonged hospital care, had a negative history and physical examination. Transfusion had been necessary during most of her earlier debridement procedures and she had sustained a bout of acute respiratory failure requiring mechanical ventilation for 2 weeks in the hospital during her admission. Progressive burn scar contractures were noted during frequent follow-up visits over the past 12 months despite the use of support dressings and mobilizing physical therapy. Arms and legs were relatively spared but the most striking physical findings were severe facial scarring limiting eye lid movement, narrowing each naris, and only permitting an irregular oral opening of approximately 2 cm by 4 cm. The child had contractures at both axillae that limited elevation of her arms above 60°. Also, neck extension and mobility was markedly limited so that the head was carried in a flexed posture and the chin was separated from the chest by a thickened 5 cm scar through which neither the larynx nor any other structure could be palpated. As this was now interfering with eating and normal activities, surgical release had been scheduled. Hemoglobin and hematocrit, urinalysis and electrolytes were normal. She weighed 38 pounds.

Plan. Discussion with the child's parents centered around the issues of blood loss, airway management, and follow-up pain control. As venous access was not deemed to be a problem, anesthetic alternatives planned were: sedated, "awake", transnasal fiberoptic intubation, attempted direct laryngoscopy under general anesthesia, fiberoptic orotracheal intubation under general anesthesia either directly or with Patil mask, and, failing these options, mask general anesthesia with surgical scar release until neck mobility would allow tracheal intubation. Sedation and topical anesthesia of the nares were discussed with the child who appeared to remember the breathing tube from her hospitalization. The anesthesiologist emphasized the fact that sedative medicines would be given by mouth or intravenously.

Course. On the morning of surgery, the child came to the hospital with her parents and was premedicated with oral pentobarbital and meperidine elixirs. She was brought to the operating room where a 20 gauge IV was placed on the volar aspect of the right wrist and monitors were applied. She was asked to gargle a solution of viscous lidocaine and to swallow it after she was placed in a semi-Fowler position with nasal oxygen insufflated. Increments of fentanyl citrate were given together with atropine sulfate. When the child appeared drowsy, her right naris was sprayed several times

with a mixture of 4% lidocaine and 0.125% phenylephrine. As an assistant standing behind the child held her head in the midline, the anesthesiologist faced her and advanced a 4.0-mm FFB carrying an uncuffed 5.5-mm nasal RAE (Mallinckrodt, Inc.) tube without airway adaptor into the posterior pharynx. The bend of the angled tube was held straight so that the FFB could pass freely through the tube. The FFB was manipulated anteriorly in order to view a normal, midline larynx and epiglottis. The child was shown her larynx and asked to phonate. Then the larynx was sprayed with 2 cc of 2% lidocaine and the instrument withdrawn to the nasopharynx as she coughed and swallowed. The child was asked to open her mouth and pant as oxygen was insufflated through her mouth and the FFB advanced through the larynx to a position about 3 cm above the tracheal carina. Some stridor was noted as the girl breathed but she was asked to inhale slowly. She appeared comfortable until she coughed as an additional cc of lidocaine was sprayed into the trachea. As the assistant held her head still, coughing subsided and the lubricated tracheal tube was advanced through the naris over the FFB with a gentle rotating motion. Despite a snug fit at the naris, the tube moved well until it encountered the larynx where it caught. A 90° turn timed with inspiration allowed it to pass into the trachea. At this point, the FFB was withdrawn and the child was given 75 mg sodium pentothal as ventilation was assisted with a mixture of 2.5% halothane in oxygen. After a satisfactory depth of anesthesia was achieved, the tube was again straightened manually as the FFB was advanced to visualize and touch the carina. It was withdrawn until the tip was just in view and the carinal/tip distance measured as the length of the FFB withdrawn. Direct laryngoscopy was briefly attempted under anesthesia and found to be quite difficult, even with a tracheal tube to guide the laryngoscopist. The larynx appeared quite anterior. No part of it could be seen below the epiglottis no matter how the head, neck and mouth were positioned.

Outcome. Surgical preparation and care proceeded uneventfully. Two units of packed cells were transfused *via* a warmer and additional 18 gauge IV that was placed after positioning. Release of the neck contracture took 30 minutes and management of the bleeders and grafting an additional hour. The axilla releases took an additional hour and first stage lip and eye relaxing incisions were made. Grafts were taken from the lower abdomen and thighs. At termination of surgery, the head, neck and chest were placed in an external brace that fixed the neck angle and the child was taken to an isolation room in the PACU where she was ventilated until awake and kept intubated on a morphine infusion. She disliked having her breathing tube in postoperatively but, in retrospect, indicated that intubation was neither frightening nor painful.

Discussion. This child presented several problems for the anesthesia and surgical teams. First, as a young child with disfiguring burns she had undergone a prolonged hospital stay during which frequent medical procedures were associated with pain and loss of control. This understandably made her, her parents, and her physicians eager to perform procedures under general anesthesia. Although older children and adults who have undergone such traumatic periods may appear calm and rational during preoperative interviews, it is rare to get them into the operating room and

through an anesthetic induction without excitement. For this reason, a reassuring review of the plan and premedication are recommended. A gradual, incremental approach to any procedure that could be painful is a good idea. Once one loses the patient's confidence, it is very difficult to repair the damage—especially with children.

Many anesthesiologists in community practice have to deal with the patients who have inflexible cervical spines. Few encounter the unique problem of an anteriorly scarred and fixed neck following burn contractures. What is extraordinary about this situation is that blind techniques for tracheal intubation that rely upon palpation or direct manipulation of structures in the neck for intubation and the emergency management alternatives of percutaneous or needle cricothyrotomy and/or slash tracheostomy are chancy at best. This suggests that it would be prudent to attempt awake techniques. Failing this, a blind nasal approach is the best alternative. Continued anesthesia with gas insufflation, binasopharyngeal airways, a mask airway or a laryngeal mask airway is possible—as is ketamine anesthesia with oxygen insufflation—but the disturbing lack of an emergency alternative makes any of these plans distinctly unappealing. A complicating factor, a contracted mouth opening, suggested that direct laryngoscopy and intubation would be quite difficult, even were neck mobility under anesthesia better than expected. Examination after the fact confirmed this. Another recent innovation, the laryngeal mask airway, most likely would not have been feasible due to the limited oral opening. Any of the low profile malleable fiberoptic stylettes (American Optical, Southbridge, MA) or the Bullard laryngoscope present possible alternative intubation devices in patients with a restricted oral airway, provided the correct angulation can be achieved.

The logical alternative for the patient with microstomia, nasal intubation, might also be limited by the scarred skin surrounding the nares. Blind procedures for nasal intubation under sedation or ketamine anesthesia have employed guided stylettes, guided tubes like the Endotrol (Mallinckrodt, Inc.), a variety of oral hooks and benders that assist angulation, magnetically guided flexible bougies, and fiberoptic transillumination. In all cases, safety is linked to preservation of spontaneous respiration with suppression of noxious airway reflexes. Surgical approaches have included escharotomy and release of tissue at the lips and/or throat after induction of anesthesia in order to allow laryngoscopy and intubation. Each of these approaches has been described after successful use by clinicians. We were prepared to use a tracheal tube as small as 5 mm ID but would most likely have performed some sort of scar release at the naris were the nasal inlet too restricted for such a small tube.

Fiberoptic intubation for this child required a small bronchoscope and some experience. The child's larynx tends to be located higher in the hypopharynx relative to other structures: consequently, it is even more difficult to achieve the correct anterior angle for the FFB when one has passed it around the tongue from the oropharynx. We chose the nasal route both because of this and the fact that it is better tolerated under light sedation. Since the neck was hyperflexed by scarring, it was even difficult to achieve the necessary acute anterior angulation from the more posteriorly

located nasopharyngeal path. A particularly trying problem for the endoscopist who has successfully passed the larynx into the trachea with the FFB was encountered here. The tube hung up on the larynx and would not pass. This problem is more common with the oral than the nasal route because the optical stylette provided by the FFB must bend more to reach the larynx from the anteriorly placed mouth. The overlying tracheal tube is even stiffer and presents an irregular surface so that it is more likely to hang up at the laryngeal inlet. When it is noted, multiple attempts to force the tracheal tube may traumatize the airway, flip the instrument outside of the trachea, damage the instrument or end in failure. Briefly withdrawing the tube over the FFB and a 90° rotation maneuver is more likely to succeed because the tip can be disengaged from the larynx and rotated so that the bevel will impinge at a different angle and pass more smoothly. Also, if glottic closure has caught the tube, the glottis may relax and present less of a barrier during the subsequent attempt. In this regard, the relative size match between tracheal tube and the carrying FFB is important. A loose fit allows greater deviation from the path of the carrying cord, thus increasing resistance during passage through the nasopharynx and larynx. The tube being passed should not be more than two sizes larger than the FFB.

Any one of several types of fiberoptic stylettes might give as good a view of the larynx in this situation but none of these would allow passage into the trachea and ensure entry of the overlying tracheal tube. Similarly the Bullard laryngoscope might demonstrate the larynx from the oropharynx but one can not be certain of passing a tracheal tube below the larynx, given the angulation involved, unless one has passed a stylette or guide wire ahead.

Conclusion. Although a number of techniques for dealing with the fixed neck and limited oral opening have been described, our own experience concurs with that of Ovassapian⁴ and others. Even in children, the FFB can provide an atraumatic means of placing an airway with minimal patient risk and convert a potentially perilous anesthetic into a relaxed, logical sequence of airway management steps that are under the anesthetist's control. One must always have alternatives in mind; however, we found the surgical alternative proposed to be least attractive and reserved it for a last resort.

ASPIRATION RISK

Anesthesia for Controlled GI Bleeding

The Problem. An emergency splenorenal shunt was scheduled for recurrent variceal bleeding in a 46 year old white man with advanced cirrhosis. An oral Blakemore-Sengstaken tube was in place that had temporarily controlled GI hemorrhage. Earlier attempts to release the balloons were followed by sudden, massive GI bleeding. The problem was to secure the airway and induce anesthesia without losing effective tamponade, allowing pulmonary aspiration of blood or hypotension from acute GI bleeding.

Presentation. The patient was transported to the preoperative area with the tamponading tube in place and both gastric and esophageal balloons inflated. The tube was secured to the chin guard of a football helmet, blocking access to the mouth. The patient had had 10 units of blood and six units of fresh frozen plasma (FFP) during the prior 24 hours as well as a vascular dye study. He was obtunded but could answer questions appropriately and follow commands when aroused. Vital signs were stable and the platelet count and coagulation profiles were acceptable.

Course. The patient was sedated with increments of fentanyl citrate as oxygen was insufflated into the airway. Monitors (including pulse oximeter) were applied, and local anesthesia was used for placement of large bore venous catheters and a radial artery catheter. Cotton-tipped applicators were used to apply a topical anesthetic and vasoconstrictor mixture to both nares. Then the nasopharynx was gently examined using a lubricated FFB (Olympus LF-1). The FFB was then withdrawn and inserted carrying a 7.5-mm endotracheal tube. The larynx was visualized and the patient was instructed to breathe slowly through his nose as the larynx was sprayed with topical lidocaine. Excess secretions were suctioned as the patient coughed and the FFB was advanced into the trachea. Following injection of additional anesthetic into the airway and suctioning, the tube was advanced over the FFB *via* the nasopharynx into the trachea and positioned about 4 cm above the carina. General anesthesia was induced with intravenous sodium pentothal and maintained with fentanyl and nitrous oxide in oxygen. Paralysis was achieved with increments of pancuronium and a pulmonary artery catheter was passed *via* the right internal jugular vein.

Outcome. After four hours of exploration, the surgeon was unable to expose the anatomy because of the distended stomach. Both balloons were deflated and the Sengstaken tube was removed. This was followed by uncontrolled exsanguination. The patient expired two hours later despite surgical and resuscitative efforts.

Discussion. In this case, the FFB allowed transnasal intubation without loss of vital GI tamponade. Direct intubation after removal of the football helmet would have been difficult because of the large orogastric tube and the anesthesiologist was concerned that manipulation of the tube would lose its tamponading effect. Later events validated the impression that it would be dangerous to remove the tube prior to induction for a rapid sequence intubation procedure. Indeed, since the patient had early signs of hepatic encephalopathy, the risk of aspiration was markedly increased even if the tube were to be removed and direct intubation attempted with several tonsil suction tips in the pharynx.

Conclusion. This high risk patient was managed in an unconventional fashion because the anesthesiologist's experience with the FFB allowed safe placement of a tracheal tube without loss of essential GI bleeding tamponade prior to the induction of anesthesia. Although it is becoming less common to see such patients as surgical candidates because of the recognition of poor surgical results, endoscopic intubation with the FFB is probably the best way to manage them in future.

Gun Shot Wound of the Neck

Plan. The anesthesiologist on call was consulted at 9 PM to evaluate a 23-year-old man with gun shot wound to the neck. The patient was said to

be oriented and awake but bleeding into the pharynx and swallowing a good deal of blood and the surgical team needed to examine the wound closely, provide pain relief, and possibly operate upon vascular structures in the neck.

Presentation. The patient was as described. No laboratory data were available and neck and chest radiographs were grossly normal. The entrance wound was noted high in the left neck with an exit lower on the right. The patient stated that he was sitting in his car when a man in the back seat pulled a gun and held it at the base of his skull, shot him, and escaped on foot. He was sitting upright with mask oxygen, an emesis basin, and a Yankauer suction that he used for spitting and suctioning blood. Bright red blood was flowing from the entrance wound in the lateral neck below the ear and the base of the skull. The patient said that his jaw hurt but that he could move it and swallow. An arterial blood gas documented respiratory alkalosis, hyperventilation and normoxia.

Plan. The problems of bleeding, asphyxiation due to aspiration and loss of the airway, and investigations of the vascular integrity of neck structures were discussed with the patient. He agreed to assist endoscopic intubation attempts by fixing his teeth on a bite block while protruding his tongue. He also agreed to nasal intubation attempts provided that topical anesthesia was used. The Emergency Department was prepared for awake tracheal intubation and/or emergency cricothyrotomy or tracheostomy.

Course. A 5 mm adult bronchoscope with 2 mm suction channel carrying a 6.5 mm tracheal tube was passed orally as the patient held a 3 cm bite block between his teeth on the side away from the injury. A pulse oximeter sensor (Novametrics) was attached to his right thumb and oxygen was given. He was asked to protrude his tongue and pant through his mouth as the anesthesiologist attempted to pass the FFB around the tongue. The patient was unable to hold his tongue still but allowed an assistant to grasp it and hold it with gauze. The patient was asked to swallow on command to clear blood and secretions. The larynx was identified with blood pooling posteriorly and the FFB was passed through the cords after several attempts that were coordinated with swallowing of pooled blood and deep breathing. Immediately thereafter the tracheal tube was advanced over the bronchoscope with a gentle twisting motion. The cuff was inflated in the trachea, the FFB withdrawn and the tube secured to the lip and around the neck with tape. Suction lavage with 1% lidocaine was performed after morphine and diazepam were administered intravenously in increments. A suction catheter was placed in the patient's mouth that allowed him to bring bloody secretions forward and he was content to lie on his side during transport to CT scan after facial and repeated anterior and lateral neck films were obtained.

Outcome. Surgical wound exploration was undertaken after CT scan and left carotid angiograms were performed under IV sedation. General anesthesia for neck exploration, evacuation of hematoma, ligation of bleeders and debridement was well tolerated. Four units of blood were transfused. Capnometry and a precordial doppler were used as monitors for venous air embolus. Injuries included the damage to left mandible and branches of the maxillary and mandibular arteries on the left and the external jugular

vein on the right. The neuraxis and facial bones were intact. The pharynx was drained percutaneously and bleeders were ligated. A surgical tracheostomy was performed and the patient was observed in the ICU overnight. The tracheostomy tube was removed two weeks later and the patient's sensory-motor function is intact after an uncomplicated course.

Discussion. Urgent indications for tracheal intubation in this case included a high probability of CNS depression associated with hypotension secondary to blood loss, direct bleeding into the pharynx, the risk of unknown neurovascular injury, and need to perform invasive and noninvasive diagnostic procedures. Also, since it was a drug related shooting by the patient's own admission, it was not known whether he had ingested any substance that might materially affect his protective mechanisms. Upper airway bleeding presents a high risk of aspiration during anesthesia and can not be prevented with cricoid pressure during a rapid sequence anesthetic induction. Another concern was that, if surgery were to be necessary, it might be extremely difficult to intubate the patient after edema accumulated or bleeding into the neck created a significant hematoma.

The major difficulties associated with tracheal intubation in this setting would be aspiration risk and, if anesthetics were used, hypotension due to vasodilatation in the setting of blood loss. If the patient were supine, his airway would have required repeated suctioning and his own protective mechanisms would have been impaired, even without drugs. Intubation with no sedative or depressant drugs and no topical anesthesia minimized the risk of each problem. Since the patient was alert, uncomfortable and knew that he was in significant danger, he was willing to undergo awake intubation. He was evidently in enough pain and distress to begin with that the FFB was not significantly more uncomfortable. It is possible to pass a through the larynx of a cooperative patient. Once the fiberoptic bronchoscope was in the trachea, it served as a stylette that permitted easier passage of the tracheal tube than either direct or blind passage would. Once the airway was secured, intravenous sedation could be titrated and vital signs closely monitored with volume replacement as necessary to prevent hypovolemia.

Choice of FFB-guided intubation *versus* other techniques was also made because it was felt that, even if intubation were impossible, the anesthesiologist could get an accurate impression of the extent of the bleeding and the position of the larynx in relation to the wound, edema and hematoma. Obviously considerable skill with the instrument must be achieved before one can attempt awake intubation without topical anesthesia or sedation. This is especially the case since laryngeal movement with cough or swallowing and blood and secretions make fiberoptic intubation quite difficult when direct trauma is the cause of airway embarrassment. The patient was able to assist by managing his own secretions, thus allowing the endoscopist to concentrate on his procedure. The presence of blood in the airway and the need for a stiffer endoscope was our indication for choice of a larger (5 mm) FFB. FFB tracheal intubation has been of assistance to us and others in the past when significant tracheal or throat injury makes the airway tenuous.⁵

Some clinicians argue that FFB takes longer. The entire intubation

sequence lasted 14 minutes. Although we were prepared with other techniques, we believed that the time required to achieve topical anesthesia of the nose, the discomfort associated with direct laryngoscopy, and the aspiration risk of general anesthesia made them less attractive. Indeed, if the patient were to be placed in the supine position, tracheostomy under local anesthesia would have been no more easily managed, safe, or comfortable than any other approach we had to offer.

Conclusion. Fiberoptic intubation can be successful under extremely adverse conditions if the endoscopist is willing to work with the patient in a position that is not the traditional, supine position for induction of anesthesia. This high risk patient was managed effectively by enlisting his assistance in the management of pharyngeal bleeding as intubation was achieved over the FFB.

Intubation of a Depressed Patient with Multiple Trauma

Problem. The anesthesiologist was called to the Emergency Department to see a 34-year-old woman who had jumped off of an 8 story parking garage in suicidal depression. Although blood gasses and vital signs were stable after fluid resuscitation, the patient was obtunded, in a neck brace, and had multiple fractures of the pelvis and lower extremities. She was said to be combative.

Presentation. The patient was supine, with cervical collar and sandbags limiting head and neck motion. She had bloody secretions in the pharynx but was maintaining her airway. Blind nasotracheal intubation had been attempted several times by the emergency room physician *via* the right naris with little success and a mild nose bleed. She did not respond to her name or light stimulation but moved vigorously and coughed in response to pain. Her vital signs had been stable for 15 minutes after release of MAST trousers and fluid resuscitation but she was tachycardic, tachypneic and appeared pale to the examiner. The teeth were clenched but gentle nasal suctioning was tolerated with minimal movement and agitation.

Plan. FFB laryngoscopy and intubation was proposed, followed by direct intubation under intravenous anesthesia, and, failing this, percutaneous or surgical tracheostomy. The traumatologist indicated that the patient had not been seen by the neurosurgical consultant yet and that inadequate lateral neck films seemed to be negative.

Course. The patient was monitored with NIBP, pulse oximeter, and ECG. The nasopharynx and pharynx were gently suctioned with an 8 French catheter. A 4 mm intubating FFB carrying a 7.5 mm endotracheal tube was advanced through the right naris until the larynx could be visualized. After ascertaining that there was very little bleeding into the airway, the endoscopist sprayed the vocal cords with 2 cc of 2% lidocaine. After suctioning secretions the instrument was passed into the trachea and the endotracheal tube passed *via* the naris to the pharynx and trachea using a gentle, rotating motion. The patient coughed briefly and was hyperventilated with oxygen as the tracheal tube was secured and the cuff inflated. The endoscope was again passed and the distance of the carina from the tip of the nasotracheal tube measured as 4–5 cm. The intubation procedure took approximately 8 minutes.

Outcome. The patient was placed on IMV with 100% oxygen, a tidal volume of 900 cc, and a rate of 10. She immediately became hypotensive and a mini-laparotomy was performed as fluid was administered. As the peritoneal lavage was negative and vital signs quickly stabilized she was taken to CT scan for evaluation of the head and abdomen. Pelvic films demonstrated multiple fractures and the abdominal CT a large retroperitoneal hematoma extending from the kidneys to partially compress the rectum and the urinary bladder. The cervical, thoracic and lumbar spine was intact and neither neurological exam or CT scanning revealed major head injury. She was observed in the ICU and open reduction of bilateral lower extremity fractures completed uneventfully under general anesthesia the next day. As she became more awake, pain was managed with patient-controlled analgesia and she was extubated 4 days after admission. This was a second suicide attempt. Severe postpartum depression had caused her to jump from a third floor window after her first child.

Conclusion. Many anesthesiologists would have elected to intubate this patient following a rapid sequence induction. In this case the anesthesia consultant felt that general anesthesia would have lowered this patient's blood pressure more than positive pressure ventilation and the risk of neck movement during direct laryngoscopy would be minimized if FFB were performed. Blind nasal intubation had been attempted with no success and some trauma. The FFB offered a less traumatic option. Direct visualization of the trachea demonstrated tracheal tube position and ensured safe placement much faster than a portable chest film. Additionally, the neurosurgeon was allowed to examine a patient who was managed with controlled airway and guaranteed ventilation without sedation or paralysis.

GLOTTIC PROBLEMS

Fixed Neck and Hoarseness Due to Rheumatoid Arthritis

Problem. A 48-year-old woman with advanced rheumatoid arthritis was scheduled for a left total hip replacement. She had been bedridden for some time and had severe arthritic deformities including an anteriorly flexed neck.

Presentation. Preoperative rounds revealed a deformed woman with ulnar deviation of wrist and fingers bilaterally, flexion contractures at the elbows and thoracic kyphosis with an anteriorly flexed neck. She was in bed with three pillows under her head and shoulders. Rheumatoid nodules were present on her elbows and above the wrists. She was markedly hoarse and complained of severe pain in ankles, elbows, wrists, hands, neck and her left hip. Her husband said that she had had several operative procedures on her legs and a total hip replacement one year previously. During that operation, he said, she had had regional anesthesia that did not work well and she was extremely uncomfortable. She and her husband requested that she be put to sleep for her surgery before the interview was underway. Upon further questioning, she revealed that she had had general anesthesia for operations on each knee, that she had been hoarse since her last

operation under general anesthesia, and that her anesthesiologist had told her that she was extremely difficult to intubate on that occasion. She stated that she had had every rheumatic drug known and had either reacted to or failed to respond to each. Examination of the neck revealed an enlarged thyroid cartilage. It did not move well with swallowing. The physical examination was otherwise normal.

Review of the patient's chart substantiated her assertions regarding arthritic therapy. Her rheumatologist had recommended surgery in order to get her out of bed. A medicine consultant opined that she was in the best possible condition for surgery. She weighed 92 pounds. Her ECG showed nonspecific changes and the chest radiograph demonstrated no infiltrates and significant kyphosis. This and the lateral neck films showed extensive degenerative changes of the thoracic and cervical spine with compression of T6-8, C5-7, and lipping with spur formation. The thyroid and laryngeal cartilages were irregularly calcified. Laboratory data were unremarkable.

Plan. Awake, sedated endoscopic intubation was recommended so that the larynx could be evaluated. Failing this, retrograde cricothyroid catheterization as a guide to FFB intubation and, ultimately, tracheostomy were presented as alternatives. Discussion centered around problems of positioning and monitoring during surgery in the lateral position.

Course. The patient was brought to the operating room with a premedication of oral diazepam. The patient was positioned with supporting pillows under the head, neck, and shoulders. Two IVs were started and a 22 gauge right radial artery catheter was placed under local anesthesia with fentanyl sedation. NIBP, pulse oximeter, and ECG were monitored. Oxygen was administered by nasal cannulae. The left naris was sprayed twice with a metered dose of 10% lidocaine and topical anesthesia achieved with 4% cocaine. A 4-mm intubating FFB, carrying a cuffed 6.5-mm endotracheal tube was advanced *via* the left naris into the oropharynx where the larynx was examined during swallowing, cough, and phonation. Extreme anterior flexion of the instrument was required for clear visualization of the larynx. Both cords moved actively but the aryepiglottic fold on the left was abnormally deviated and the left arytenoid cartilage appeared subluxed. Several nodules were evident on the vocal cords bilaterally. The larynx was sprayed with 2 cc of 2% lidocaine solution and the FFB advanced into the trachea. Lidocaine was injected just above the carina and secretions suctioned as the patient coughed. As the FFB was held with slight counter traction, the tracheal tube was advanced through the naris into the pharynx and, thence, passed through the larynx into the trachea. Three attempts were required before the tracheal tube would pass into the larynx with gentle pressure and 90° rotation as the patient inhaled. Anesthesia was induced with 75-mg increments of sodium pentothal and maintained with 1% enflurane in nitrous oxide 60° and oxygen. Surgery was uneventful with an estimated blood loss (EBL) of 700 cc. At the end of the procedure, the patient was taken to the PACU, ventilated with partial support by IMV, and placed in bed at a 60° elevation with shoulders, neck and head supported. She was extubated two hours later over the FFB after adequate swallowing function was demonstrated. The larynx was unchanged.

Outcome. Upon extubation, the patient revealed that the intubation procedure had not been uncomfortable. Her voice was unchanged and follow-up otorhinolaryngologic consultation was sought. Laryngeal findings before and after extubation were documented in the progress notes of the chart.

Discussion. Rheumatoid arthritis can present many problems for the anesthesiologist, not the least of which involve the airway. Degenerative changes of the spine and joints increase the risk of injury during positioning and surgery. TMJ involvement may limit mouth opening. Laryngeal involvement can include inflammatory nodules and changes in the articulation of the laryngeal cartilages that lead to laryngeal immobility, incompetence, or obstruction. Pulmonary involvement may range from interstitial lung disease, that increases respiratory load and the tendency to develop hydrostatic pulmonary edema, to acute infiltrates and hypoxemia. A number of toxic therapies can superimpose organ system compromise and decrease the anesthetic margin of safety.

When one has abnormal laryngeal function or structure, this should be investigated as well as evidence for other organ system dysfunction. Anesthetic plans should be formulated and communicated so that there will always be an orderly progression from least invasive or risky to the most.

Conclusion. A potentially hazardous anesthetic was converted into a controlled situation by placement of an endotracheal tube using FFB. The anesthesiologist was also able to document the extent of laryngeal injury that was preexistent and compare it with the postoperative picture.

Stridor Following Subtotal Thyroidectomy

Problem. A general surgeon stopped by the anesthesia lounge and asked us to look at a 63-year-old woman in the ICU who had just been extubated and seemed to have stridor that did not respond to aerosol therapy with racemic epinephrine. The patient had a subtotal thyroidectomy on the preceding day.

Presentation. The patient was slender and was sitting at 90° with a 40% aerosol mask. Stridor with inspiration and expiration was audible across the unit. A closer look demonstrated retractions and moderate use of accessory muscles. Blood pressure and heart rate were normal but respiratory rate was 32. An arterial blood gas was 7.46 135 32. She could barely phonate. The critical care nurse said that she had been breathing like this for 2 hours since extubation and had not responded to two treatments with racemic epinephrine. The patient failed a trial of extubation in the operating room and was re-intubated under anesthesia and ventilated overnight in the surgical ICU.

Plan. The surgeon was called and FFB laryngoscopy with intubation proposed. He agreed to the plan. This was discussed with the patient who agreed to laryngoscopy but refused reintubation.

Course. Topical anesthesia of the naris was achieved with 1.5 cc 4% cocaine. A 4 mm intubating FFB (Olympus™ LF-1) was passed into the pharynx from the naris through a side hole in the aerosol mask with the patient in the sitting position. Both vocal cords were noted to be fixed in the paramedian position. The patient was neither able to approximate nor open them and paradoxical motion was noted with respiration.

The implications of this were discussed with the patient after laryngoscopy. She refused intubation. She was told that, if she became tired or showed more dramatic signs of respiratory failure, intubation would become necessary.

Two hours later the anesthesiologist was again called to the bedside. The patient was less alert and, when aroused and asked, indicated that she couldn't get her breath and desired intubation. The FFB was again passed through the nose using topical anesthesia carrying a 7.0 ID tracheal tube. It was easily passed through the larynx and the tracheal tube passed over it. The patient was placed on 5-cm CPAP. She indicated that her breathing was much better.

Outcome. Two days later, the patient was extubated over the FFB. At this time the left vocal cord moved appropriately and the patient demonstrated an effective cough and complete laryngeal closure with swallowing. She was placed again on an aerosol mask and transferred from the ICU on the next morning. Her voice was hoarse, as was noted preoperatively (in retrospect).

Discussion. It seems likely, in retrospect, that this patient had had a unilateral vocal cord palsy to begin with. Edema or trauma from surgery injured her recurrent nerve on the right and left her with bilateral loss of function and no way to compensate. An alert anesthesiologist might have either referred the patient to an otolaryngologist or performed the evaluation preoperatively himself with a FFB. Tracheal CT scanning in the preoperative period has been recommended when patients with large goiters are referred for thyroidectomy since a significant number of them have tracheal compression as well. The FFB offers the anesthetist a unique opportunity to evaluate the larynx and subglottic areas as well as a useful means of atraumatic intubation.

Other anesthetists would have laryngoscoped this patient with topical anesthesia and sedation or intubated her under intravenous anesthesia. Since she did not want to be reintubated, the FFB allowed diagnosis without risk of further airway compromise. It also permitted translaryngeal intubation with minimal risk of further glottic injury. When it was thought appropriate to repeat the evaluation, this could be done with the FFB in the controlled setting of the ICU and no sedation. Other techniques either involve direct laryngoscopy "cold turkey," with no topical anesthesia, or general anesthesia. Commonly recommended alternatives for the repeat evaluation of an intubated patient are extubation and the trial of fire, general anesthesia in the ICU or operating room with evaluation by laryngoscopy during emergence, or mirror laryngoscopy after extubation by an otolaryngologist.

Conclusion. A patient with vocal cord paralysis following thyroid surgery was evaluated and intubated fiberoptically in the ICU of our community hospital. Follow up evaluation with the surgeon was possible without general anesthesia because the FFB could serve as a laryngoscope as well as a re-intubation guide should the larynx be persistently nonfunctional.

SUBGLOTTIC AIRWAY PROBLEMS

Persistent Cuff Leak in a Patient with Laryngeal Cancer

Problem. The medicine residents covering the ICU consulted an anesthesiologist because of an intubated patient with an apparent tracheal cuff leak. The patient had known laryngeal cancer and upper airway obstruction that had led to translaryngeal intubation and mechanical ventilation.

Presentation. The patient was a 48-year-old man weighing 76 kg who was alert and oriented. He had been admitted in respiratory distress that progressed over several weeks previously and was intubated in the emergency department shortly after admission because of cyanosis, stridor with retractions, and an arterial blood gas revealing hypoxemia and hypercapnea with respiratory acidosis despite oxygen therapy and racemic epinephrine aerosol. He had an extensive smoking history with progressive hoarseness noted during the past year. Upon examination he was found to be well developed with an essentially normal examination except for peripheral wheezes in both lung fields and a loud air leak auscultated in the neck with each positive pressure breath. He was intubated with an 8 mm ID Ohio tracheal tube. The respiratory therapist stated that he was not returning his volumes from the ventilator and noted a tracheal cuff leak that did not improve despite additional volume in the cuff. The patient was moderately tachypneic on IMV of 8 with a tidal volume of 1000 cc. Spirometry demonstrated that the ventilator was delivering 950 cc to the tracheal tube upon inspiration but that the patient only exhaled 450 cc. Spontaneous tidal volumes were 3–400 cc between mandatory breaths.

Course. The tracheal tube cuff was tested and found to return the volume of air injected each time it was inflated. It contained 25 cc of air when first deflated. The tense pilot balloon was rechecked by sealing it with a three way stop cock. Air was heard returning from the mouth each time the ventilator cycled and the orotracheal tube was secured at the 23-cm mark in this 5'10" tall male, but the magnitude of the air loss seemed to vary as head and neck position changed.

The patient was sedated with intravenous diazepam, 10 mg, and morphine, 15 mg, in increments. Upon loss of the lid reflex, a brief, direct laryngoscopy was performed that demonstrated that the tracheal tube was in the larynx with the cuff below the vocal cords. The cuff could be balloted below the cricoid cartilage when inflated and deflated and was noted to be firm.

The patient was placed on 100% oxygen for five minutes as the FFB and light source were obtained. A 6 mm adult FFB was passed *via* a ventilating adaptor until the trachea could be visualized. Just at the tip of the tracheal tube, the posterior membranous trachea appeared to be thickened and erythematous. The tracheal tube cuff was deflated and it was withdrawn 5 cm back toward the larynx as the FFB viewed the trachea. A 3 cm by 1 cm erosion was noted in the posterior membranous trachea with heaped up, inflamed, irregular mucosa surrounding the area. This was recognized as a tracheoesophageal fistula. The tube was advanced to a position only 2 cm above the tracheal carina and the cuff reinflated.

Ventilation was again assessed after the FFB was withdrawn. There was no cuff leak and the patient exhaled 940 cc with each positive pressure breath. ENT consultation was sought and the attending pulmonologist was informed of the diagnosis.

Discussion. The anesthesiologist is often the most knowledgeable consultant in the hospital when ventilated patients develop airway problems. By systematically measuring ventilator volumes delivered at various parts of the circuit and comparing these with exhaled volumes, the volume loss could be clearly shown to be between the system and the patient. The next logical possibilities were tracheal cuff dysfunction or tube displacement. As the cuff appeared to be intact and the leak was a function of head and neck extension, the most common cause would have been a tracheal tube cuff that had been hyperinflated and worked its way into the larynx above the cords. This did not seem to agree with the position of the cuff when it was balloted during inflation and deflation. Since ventilation was adequate, the consultant had time to thoroughly investigate the problem. Direct laryngoscopy under intravenous sedation offered the most convenient option. When the tracheal tube was found to be in place and the cuff/pilot balloon system intact, it was evident that the problem had to be within the patient. Traumatic tracheoesophageal (TE) fistula secondary to high pressure tracheal cuffs rubbing posteriorly against a stiff nasogastric tube is a rare finding. More commonly, the nasogastric (NG) tube is passed into the trachea and causes an intermittent cuff leak that varies with head and neck movement. In this patient, it was evident that cancer had been the major cause of a fistula that complicated his upper airway obstruction by allowing periodic aspiration. It is most likely that initial tracheal intubation placed the tracheal tube cuff at or below the site of the weakened posterior membranous trachea. Initial ventilatory support was uneventful but with head and neck movement the tube pulled back to a point where the cuff was imperfectly sealing the fistula.

Comment. Many anesthesia consultants would have simply changed the tracheal tube. Given the unusual pathology, it is likely that a new tube would have sealed the leak and that it would have recurred periodically to challenge the ICU staff. An astute clinician with the right instrument can make the diagnosis of TE fistula at the bedside without recourse to bronchography or other radiographic procedures.

SVC Syndrome with Mediastinal Mass

Problem. Mediastinal exploration was scheduled for a patient with a symptomatic anterior mediastinal mass. On the day before surgery, the thoracic surgeon contacted the assigned anesthesiologist to warn him that the patient appeared unusually dyspneic.

Presentation. When the anesthesiologist made preoperative rounds he found a 64-year-old man who had cyanosed upper extremities in the sitting position and demonstrated noisy breathing. The patient gave a history of progressive dyspnea with exercise and revealed that his sleep was disturbed and that he could only sleep on his right side on three pillows. He also stated that his voice had been hoarse for several months. His wife corroborated this and noted that he had seemed to be more or less blue on

occasion over the past few weeks. All pulses were intact, but the neck and arm veins appeared distended. No wheezing was noted, and the chest was clear although upper airway sounds were coarse and radiated throughout the chest. The heart sounds were regular and did not change greatly as the patient was positioned supine, on left and right sides, and sitting although he was more dyspneic on his left side and supine during these maneuvers.

Review of the chart revealed that the chest radiograph showed widening of the mediastinum superiorly and to the right with deviation of the tracheal air column to the left. Thoracic computerized tomograms demonstrated an anterior mass that narrowed the trachea just below the larynx and caused it to deviate to the left. No endotracheal or bronchial projections were noted. The mass seemed to surround the superior vena cava. The presumptive diagnosis was cancer but, because of the severity of the patient's symptoms, the oncologist, pulmonologist and internist had asked the thoracic surgeon to attempt to decompress the superior vena cava (SVC) and trachea while obtaining definitive tissue for biopsy. Laboratory tests revealed a high platelet count and mild hypoxemia on room air ($\text{PaO}_2 = 78$).

Plan. The thoracic surgeon and oncologist were contacted and asked if radiation therapy might not reduce the risk of anesthesia and surgery. Both felt strongly that surgical therapy presented the only appropriate course in the situation. The surgical team arranged to have an extracorporeal circulation team and equipment on standby. A frank discussion of the implications of vena caval obstruction and tracheal obstruction was held with the patient and his wife. Sedated fiberoptic intubation was recommended in the sitting position as well as placement of inferior extremity venous catheters, an arterial catheter, and a femoral central venous pressure (CVP) catheter. High dose narcotic anesthesia was proposed with postoperative ventilation and delayed extubation.

Course. On the morning of surgery, the unpremedicated patient was brought to the operating room where supplementary oxygen was administered as monitors were applied in the sitting position. Increments of fentanyl citrate were administered and peripheral venous and arterial catheters were placed under local anesthesia. A 16 gauge, 8 inch external jugular catheter was passed under local anesthesia with the head at 60° using the Seldinger technique and a "J" wire. The patient was asked to gargle viscous lidocaine several times and spit out the residual into an emesis basin. The endoscopist stood in front of the patient and maintained visual contact with him while an assistant monitored the vital signs and oxygen saturation. A bite block was placed between his teeth and he was asked to protrude his tongue. A 5 mm FFB was passed around the tongue to the posterior pharynx. With anterior flexion of the instrument, the larynx could be seen and the vocal apparatus was sprayed with 2% lidocaine on two occasions. The right vocal cord was found to be relatively immobile in the paramedian position. The patient was instructed to breathe slowly and the larynx was passed without discomfort. Topical anesthetic was injected into the trachea and the FFB withdrawn as the patient coughed briefly. The trachea was again entered and the diameter, length, and position of the stenosed area viewed from above during quiet breathing. Paradoxical

closure of the stenosed area was noted with inspiration. The FFB was withdrawn and passed through a 7-mm ID tracheal tube. The patient was intubated and the tip of the tube placed just above the carina—where it was thought the cuff would be below the stenosed segment. Following this, anesthesia was induced with midazolam and fentanyl and the head gradually lowered.

Outcome. Venous pressure measured in the SVC was 28 torr while CVP measured through a long 16 gauge catheter passed from the femoral route was 6 torr with the head at 15° elevation. The groin and chest were prepped. A large irregular mass was found upon median sternotomy that extended from the right anterior mediastinum across the trachea and invested the SVC to the upper portion of the atrium. It was divided and removed, except for portions that adhered to the vena cava and right atrium. After the procedure the venous pressures became 14 and 8, respectively. Blood loss was less than 2 units. The patient was taken to the ICU and ventilated. On postoperative day 2 the patient's face and upper extremities were swollen and cyanosed and an FFB was again passed to evaluate edema of the trachea and assess the safety of extubation. At that time the carina was markedly blunted and the tracheal mucosa appeared quite edematous and cyanotic. The patient was maintained on the ventilator and nursed in the sitting position for 2 more days when repeat bronchoscopy demonstrated a marked decrease in the edema and he was uneventfully extubated over the FFB which was then withdrawn for post-extubation laryngoscopy. Right vocal cord paralysis persisted but protective laryngeal mechanisms appeared grossly intact. A racemic epinephrine aerosol was administered every four hours for three doses. Hoarseness persisted for several weeks and gradually resolved after a course of radiation therapy for lymphoma.

Discussion. This critically ill patient presented with a life-threatening problem that has been well documented.³ Grave hemodynamic and respiratory problems that are not amenable to routine resuscitative measures can follow the induction of anesthesia in such patients. One can assure that the airway will not be mechanically obstructed if a tracheal tube can be placed below the edematous upper airway or the tracheal stenosis as a stent, but one cannot be certain that pulmonary edema associated with mechanical obstruction of the pulmonary veins or circulatory collapse secondary to mechanical compression of the heart will not follow positioning such patients for surgery without a careful evaluation and plan. Pump standby was provided on this account.

Awake intubation with an FFB allows the anesthetist to evaluate the severity of upper airway edema and the magnitude of the problem in a dynamic way that can not easily be duplicated by CT or magnetic resonance imaging. The instrument was of use postoperatively as well since it allowed assessment of the larynx and the probability that a trial of extubation would succeed. In fact, it was possible to extubate the patient over the FFB with a direct assessment of laryngeal function at the time of extubation. In this case, reintubation would have been a simple matter of passing the FFB translaryngeally again and readvancing the tracheal tube.

Conclusion. A complicated patient with combined upper airway and

SVC obstruction had airway management facilitated by use of the FFB. It allowed the anesthesia and surgical teams to directly evaluate the airway, place a stenting tracheal tube in the best position, re-evaluate the trachea, extubate the patient, and document laryngeal function.

FIBEROPTIC FAILURES

Morbidly Obese Patient with a Difficult Airway

Problem. The department chairman was paged STAT over the operating room intercom to an operating room where a patient was difficult to intubate. En route, he was asked to bring the FFB or fiberoptic stylette.

Presentation. A 5-foot, 138 kg, 44-year-old woman was added to the surgical schedule late the preceding day for abdominal hysterectomy and seen by the call anesthesiologist. A staff nurse anesthetist had undertaken to induce general anesthesia by herself because the supervising anesthesiologist was busy in another room. When she had difficulty ventilating the patient, a passing anesthesiologist came into the room and assisted with intubation attempts. Further assistance was called when neither the Certified Registered Nurse Anesthetist (CRNA) nor anesthesiologist could intubate the patient. Two other experienced anesthesiologists responded and helped to maintain the airway. Each attempted intubation using a variety of laryngoscope blades, blind attempts with various stylette angles and blind nasal intubation. The patient had had several large doses of sodium thiopental and succinylcholine with intravenous fentanyl, 3 cc, prior to induction. She was being ventilated with 100% oxygen and the NIBP, ECG, and pulse oximeter demonstrated hypertension (190/110 mm Hg, with an appropriately sized cuff), sinus tachycardia (130 beats/min), and arterial desaturation (79–84%) as one anesthesiologist held the airway with two hands while another managed the reservoir bag. Oral and binasopharyngeal airways were in place. Arterial desaturation had been noted for at least five minutes. Spontaneous respiratory activity was evident. The stomach was noted to be distended and the patient was in a reverse Trendelenberg position.

Plan. The consultant felt that attempted FFB intubation would be unsafe. Since the patient was hypoxemic and distressed, immediate cricothyroid ventilation was recommended if conditions deteriorated. All involved preferred recovery from anesthesia and postanesthetic monitoring for hypoxemic organ system injury, if possible. Postponement of surgery was agreed upon with the surgeon.

Course. Over the next few minutes spontaneous respirations became more vigorous and evidently less obstructed with extreme extension of the neck, jaw lift, and 10-cm CPAP. Oxygen saturation rose to the 90s and the patient began to move spontaneously. When she maintained oxygenation without CPAP, she was transported to the PACU with a Mapleson system and oxygen tank. Oxygen saturation on room air in the sitting position 2 hours afterwards was 95%.

Outcome. No adverse sequelae followed. The patient was informed

that there was a major anesthetic risk, that she could not be intubated, and the reasons for cancellation of her operation. A return for planned, awake intubation was recommended. Her anesthetic course was extensively documented. Departmental protocol for supervision of CRNAs was reiterated and tightened.

Discussion. The many challenges of morbid obesity have been extensively documented. The salient point of this FFB "failure" is that FFB should not ever be attempted in this situation. The setting, significant and symptomatic hypoxemia, is not one in which there is time for either interruption of ventilation or persistence with a failed technique (*e.g.*, mask ventilation) until a major dysrhythmia or other hypoxia related complication occurs. Indeed, no fiberoptic instrument is likely to work when a number of individuals have repeatedly traumatized the airway and induced bleeding and edema.

If four experienced anesthesia personnel have failed to achieve anything resembling adequate laryngeal exposure in such a patient, it is also unlikely that an otolaryngologist or a thoracic surgeon could find the airway with a rigid bronchoscope. Percutaneous catheter placement *via* the cricothyroid membrane can effectively oxygenate a patient whose airway obstruction prevents oxygenation; however, the lesion that causes hypoxemia in morbid obesity often includes loss of lung volume and consequently increased relative "shunt" with a higher than normal oxygen uptake. Simple oxygen insufflation can not restore FRC effectively. Needle/catheter cricothyrotomy for jet ventilation and percutaneous cricothyrotomy or surgical tracheostomy would restore lung volume and allow oxygenation in this setting. These techniques assume that the anatomy of the neck is recognizable and that the tube or catheter inserted is long enough for the obese neck. Given the probable difficulty of these techniques in such a patient, it would seem wise to allow emergence from anesthesia before trying an elective airway maneuver.

Finally, after a sustained episode of hypoxemia, it is unwise to persist with anesthesia and elective surgery. Demonstration of an hypoxic insult may take hours as organ system injury evolves. Since subsequent anesthetic events or surgical misadventures could exacerbate such injuries, the prudent course was to cancel surgery and observe the patient—thus avoiding a secondary insult. Although cancellation makes it obvious to both the patient and the surgeon that an anesthetic failure has occurred, one is better off with a red face than with a brain injured patient.

Conclusion. In some settings attempted FFB for laryngoscopy, tracheal intubation or any other purpose is inappropriate—not a technical failure.

Parturient with HELP and Fetal Demise

Problem. A colleague asked for assistance intubating an obese 26-year-old primagravida with HELP syndrome who had intrauterine demise, severe coagulopathy, and oligurea. He reported a stable airway under general anesthesia in this obese patient but neither he nor an experienced CRNA had been able to intubate the patient despite a partial view of the larynx and epiglottis at laryngoscopy.

Presentation. The patient had been admitted several hours previously

in transfer from a smaller community hospital because of progressive deterioration during hospitalization for severe preterm pre-eclampsia. On admission, the fetal monitor demonstrated an agonal heart rate but, because the patient was severely coagulopathic, oliguric and had evidence of hepatic and renal dysfunction, it was decided to optimize maternal outcome. Initial clinical plans were to correct maternal hemodynamics and improve coagulopathy since fetal viability was lost. Clinical findings and ultrasound suggested extensive or total placental abruption. The patient was edematous, obese and had poor peripheral veins.

The obstetric anesthesia team took the patient to the operating room where fetal monitoring continued and a pulse oximeter and ECG electrodes were applied. Both a radial arterial catheter and a large bore intravenous catheter were placed. Platelets were on order and FFP was infused. Multiple attempts to locate and cannulate the right internal jugular vein were made with no success. Finally, an antebrachial vein was cannulated and a 7.5 French pacing pulmonary artery catheter was passed. Hemodynamic data confirmed the impression that the patient would tolerate more plasma volume expansion as blood pressure was controlled. When platelets were available, general anesthesia was planned. Maternal heart rate, blood pressure, respirations and neurologic signs were stable at this time although clotting parameters, bleeding time, and platelet count were still abnormal. Although parameters were not optimal, it was felt that the coagulopathy would not be resolved as long as an abrupted placenta and moribund fetus were in the uterus.

Course. Anesthesia was induced with sodium pentothal and succinyl choline after a dose of oral clear liquid antacid. When ventilated with cricoid pressure, the airway was adequate and oxygen saturation stable; however, repeated attempts at translaryngeal intubation by both the CRNA and anesthesiologist failed. When the fiberoptic endoscopist arrived on the scene, the airway appeared to be worse and arterial saturation on 100% oxygen was in the mid 90s. The airway was suctioned and several attempts to identify the larynx made as mask ventilation continued with a Patil-Syracuse mask. Each time bloody secretions obscured the field. A combined attempt was made as oxygen was insufflated into the airway with direct laryngoscopy and the tip of the FFB was manually directed towards the epiglottis. The laryngoscopist commented that things appeared to be deviated towards the left. Dramatic arterial desaturation to 80% was immediate. Attempts at FFB were discontinued. Following restoration of mask ventilation there was a slow rise into the 88% range. It was noteworthy that extreme traction on the jaw and forceful neck extension were required to maintain a patent airway with the saturation rising to 90%.

The neck was palpated and right sided swelling noted. A percutaneous needle placement via the cricothyroid or tracheal cartilages was attempted and an ENT consultant was called for assistance. Neither the larynx nor trachea could be palpated and air could not be aspirated through a percutaneous tracheostomy insertion needle (Pertrach, Bridgeport, West Virginia) at any point in the midline or towards the left. Percutaneous cannulation efforts were discontinued and an otolaryngologist arrived soon thereafter. Mask ventilation was continued as a hurried tracheostomy was

performed. The procedure took longer than expected because the otolaryngologist had difficulty locating the trachea. A layer of dark blood was noted in the superficial tissues and the trachea appeared deviated to the left. No tracheostomy tube on the emergency set was long enough to leave in the trachea so cuffed endotracheal tube was sutured into position pending arrival of a better tracheostomy tube.

Outcome. The cesarean section proceeded as planned and a preterm fetus was stillborn as expected. Coagulation factors and platelets were replaced. The patient required multiple units of transfusion. She was transferred to the ICU postoperatively and ventilated for several days. The tracheostomy was revised the night following surgery. Transient renal, respiratory, and hepatic failure resolved with no long-term morbidity. The patient was discharged from the hospital after two week's hospitalization.

Discussion. In this case an adequate airway gradually deteriorated despite effective anesthesia and muscle relaxation. The patient's hemodynamics improved with coagulation factor and platelet replacement, plasma volume expansion and blood pressure control. The airway was unobstructed prior to anesthesia yet laryngoscopy became progressively more difficult as time passed. Both the CRNA and the anesthesiologist's initial impressions were that the larynx was almost in view and that they needed some assistance placing a stylette or angling the tube in the appropriate direction. Fiberoptic laryngoscopy was difficult and the patient became critically hypoxemic during intubation attempts. The mask airway became progressively harder to manage and was finally tenuous with maximal efforts to extend the neck and lift the jaw anteriorly. When cricothyrotomy was attempted, the anesthesia care team noted that the cricoid cartilage was no longer palpable. It seems likely that these problems were due to an expanding hematoma in the neck of this obese patient with bleeding diathesis. This could explain our difficulty needling the trachea percutaneously as well as the problems with tracheostomy. Attempting to obtain central venous access, no matter how carefully, is ill advised by any route that can not be directly seen and sutured when a severe coagulopathy is manifest. An expanding hematoma in the neck is more common following arterial puncture than venipuncture. Arterial puncture is reported 1–2% of the time during internal jugular cannulation attempts. This suggests that one would do better to use the safer, albeit less certain, routes from external jugular, antecubital or femoral veins in thrombocytopenic or coagulopathic patients.

Other possible problems that could have made the airway progressively more difficult include the patient's obesity, failed attention to maintaining anesthesia and paralysis, secretions, and/or aspiration. In any event, critical hypoxemia and airway management failure indicate immediate, definitive therapy for airway support. If such patients cannot be intubated orally, some other airway must be provided. Anesthesiologists have become facile with the Seldinger technique for venous and arterial cannulation. This has also been adapted for percutaneous cricothyrotomy, tracheotomy, and thoracentesis. Regardless, when the anatomy can not be found blindly or by palpation, nothing other than direct surgical exploration of the neck and tracheostomy can be recommended. The FFB is not a helpful instrument in such an emergency.

Comment. Direct visualization of airway structures and intubation with a FFB requires time and controlled circumstances. When the anatomy is abnormal, this is even more important. It is not surprising that FFB fails when the airway is distorted and filled with bloody secretions that veil the view. A critically hypoxemic or arrested patient requires the fastest artificial airway that can be placed. If translaryngeal intubation is not possible, surgical tracheostomy or cricothyrotomy presents the only acceptable alternative.

CONCLUSION

The FFB is a versatile instrument that can be used for a number of therapeutic and diagnostic purposes that suit the anesthesiologist. These include tracheal intubation, nasal and laryngoscopic exams, tracheal lavage for secretion management, tracheal tube change, bronchial blockade and endobronchial tube placement for selective ventilation. These cases reflect the broad range of uses that the practising anesthetist can find for the FFB. This instrument is practical, convenient, user-friendly and versatile. It belongs in the anesthesiologist's technical armamentarium. Its utility justifies the effort—even in community practice.

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Address reprint requests to

Dr. Charles B. Watson, MD
Department of Anesthesiology
Bridgeport Hospital
267 Grant Street
P.O. Box 5000
Bridgeport, CT 06610

Fiberoptic Bronchoscopy in the Pediatric Patient

Natan Noviski, MD,* and I. David Todres, MD†

Since the introduction of the flexible fiberoptic bronchoscope (FB) in the early 1970s, its clinical application in diagnosis and treatment has expanded greatly.¹⁴ It is used by a broad spectrum of medical specialists such as the pulmonologist, intensivist, anesthesiologist, and otolaryngologist. Initially its use was limited to adults and some authorities suggested that its use should be limited to children above 10 years of age, preferring the rigid bronchoscope for small children.¹⁰ The main reason for this concern was the small size of the airway in the infant and, the difficulty obtaining adequate ventilation with a flexible instrument that was too large. At this time, too, the development of fiberoptic telescopes with the small caliber ventilating rigid bronchoscope and the addition of a video camera allowed the pediatric bronchoscopist in the late 1970s and early 1980s safer and better visualization of the airway of the infant.⁸

The use of a smaller size flexible bronchoscope (FB) for pediatric use was reported in the late 1970s.¹⁸ It had no suction channel and it had controlled flexion of the tip. This FB has been modified by attaching an external suction channel, thus limiting its use to infants above 18 months of age. In 1978, the pediatric flexible bronchoscope was developed with an outside diameter of 3.5 mm and a 1.2 mm suction channel. Since that time, a large amount of experience has been gained with pediatric FB.^{3, 5, 6, 8, 12, 15, 18, 19} Later, ultrathin bronchoscopes, such as the 2.7 mm, 2.2 mm, and even the 1.8 mm, with varying characteristics and limitations, became available.^{4, 6, 12, 15, 16, 17}

The differences between the rigid and flexible bronchoscope are found in the size, flexibility, auxiliary instrumentation, optics, and the type of sedation used in each of the procedures. The FB is sized according to outer diameter (e.g., 3.5 mm) and the patient must breathe around it. The rigid bronchoscopes (RB) (Fig. 1) are sized according to their internal diameter;

*Pediatric Pulmonologist, Hadassah University Hospital, Jerusalem, Israel; Fellow, Pediatric Intensive Care Unit, Massachusetts General Hospital, Boston, Massachusetts

†Director, Neonatal and Pediatric Intensive Care Units, Massachusetts General Hospital, Boston, Massachusetts

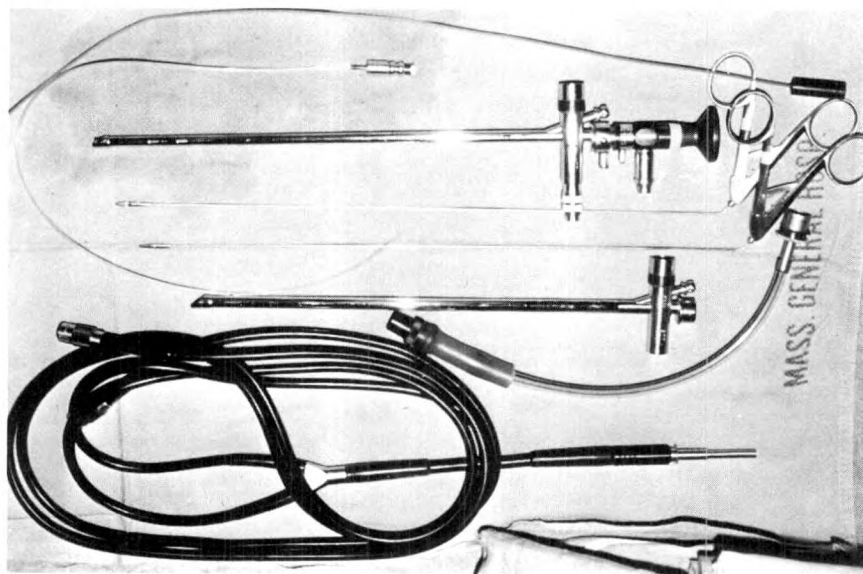


Figure 1. Rigid bronchoscopes.

thus, a 3.5 mm RB has a 4–4.5 mm outer diameter and therefore are large enough in their inside diameter to allow the patient to breathe through them. RBs as small as 2.5 mm are available. The RB allows the passage of various instruments through the lumen. This includes suction catheters, forceps for biopsies and extractions of foreign bodies, Fogarty catheters to tamponade bleeding, etc. In the pediatric FB we are limited to the use of the suction channel's lumen (1.2 mm internal diameter) and very few instruments can be passed through it. Concerning the optics, the glass rod fiberoptic telescope which is used through the RB is the best in terms of optical performance.^{9, 20} These telescopes are available in various sizes (the smallest being a 2.5 mm) and with various wide angles (30 and 70 degrees) in its tip. The advantage of the optics in the FB is its flexibility that allows one to visualize areas the RB may not reach, such as the apices of the lung. It also allows a study of the dynamics of the airways, especially the upper airways. The FB can be used with mild sedation and local anesthesia in the majority of cases. RB is used with general anesthesia in the pediatric patient.⁹ In our opinion, RB under general anesthesia is more appropriate when investigating the posterior aspect of the larynx and upper trachea for a tracheoesophageal fistula (H-Type), biopsies, therapeutic excision of tissue from the airways, foreign body extraction, when bleeding from the airways (as in the investigation of hemoptysis) is expected during the procedure and in a ventilated patient in which the FB cannot be passed through the endotracheal tube. Apart from these indications, one may successfully use the FB in virtually all other situations. Both techniques should be available for the pediatric patient and individualized to each patient according to the clinical condition. We shall focus mainly on the use of the pediatric FB, as

anesthesiologists are less familiar with this device in the pediatric patient than they are with the RB.

TECHNIQUES

The standard pediatric FB is 3.5 mm in its outer diameter. It consists of a flexible shaft through which pass two bundles of glass fibers and one suction channel of 1.2 mm. Light is brought to the tip of the bronchoscope by one bundle of fiberoptic glass and the other bundle carries the image. The distal 2–2.5 cm of the instrument is flexible and can be flexed approximately 160 degrees in one direction and 60 degrees in the opposite direction. The suction channel is used to suction, irrigate the airway, and perform bronchial lavage and to pass a cytology brush and very small grasping forceps and baskets. Smaller diameter bronchoscopes (1.8, 2.2, and 2.7 mm) are available. Most of them have limited manipulation of the tip and no suction channel. It is possible to perform FB in the intensive care unit, operating room, or at the patient's bedside in the ward. However, unless there is a strong contraindication, FB should be done in a specific place where most procedures are performed. Thus the bronchoscopist will have all the instruments, monitors and medications necessary and the safety of the patient will not be compromised. In some units, a mobile cart is used. It has the equipment and drugs necessary for an FB and resuscitation. The bronchoscopist needs to be assisted by skilled assistants. The roles of the assistants are preparation and stabilization of the patient, monitoring the patient's heart rate, adequacy of ventilation, oxygen saturation (pulse oximetry), color, assisting the bronchoscopist during the procedure, and post-procedure care of the patient.

Bradycardia is a sign of severe hypoxemia and the bronchoscope should be withdrawn and oxygen administered to the patient. Generally we do not monitor the PCO_2 and there are reports of transient CO_2 elevations during the procedure.¹⁹ Therefore, the procedure should be performed very quickly and should last less than 30 seconds in the small infant. Note that the bronchoscope should not block the small airway of the small infant for a prolonged period of time. Repeated insertions may be necessary to achieve the goals of the bronchoscopy. A special advantage of FB is that its use almost never requires general anesthesia. Therefore, potential anesthetic complications are minimized.

All patients should be sedated unless they choose not to be. This generally applies to the older pediatric patients who wish to watch the procedure on the video screen. Premature newborns, or other patients who have severe respiratory compromise and run the risk for respiratory depression should receive minimal or no sedation. For young infants who need rapid nasopharyngoscopy topical anesthesia only is used. The patient should be given nothing by mouth (NPO) for 4 hours and should have an intravenous line in place. The first step in the sedation process begins with appropriate psychological preparation for the patient. An explanation of what is to be done given in a positive and relaxing way, patience, and good communication generally result in the cooperation of the child.

Concerning the medications used, there are several options.^{6, 20} Most medications should be given intravenously. One may administer IV meperidine only or a lytic cocktail [meperidine (2 mg/kg), promethazine (1 mg/kg), and thorazine (1 mg/kg)] given intramuscularly 1 hour prior to the procedure. We generally do not use fentanyl due to the possibility of muscular rigidity. We do not favor the benzodiazepines as these agents are not counteracted by specific antidotes if necessary. Some bronchoscopists supplement the sedation with methohexital for selected short procedures.¹⁹ A dose of 1–2 mg/kg intravenous will result in a rapid induction of deep sedation. However, this anesthetic agent may produce severe respiratory depression and should only be employed by skilled individuals prepared to assist ventilation. We generally use chloral hydrate for the small infant and child, in a dose of 75 mg/kg given orally 30 to 45 minutes before the procedure. Just prior to the start of the procedure we administer meperidine, 1–2 mg/kg intravenously.

Topical anesthesia is essential throughout the FB. We employ lidocaine without preservatives, 5 mg/kg, for the total procedure. Its action lasts for approximately 20 minutes. It may be instilled before the procedure directly into the nose and then over the airway mucosa through the suction channel. It is essential to achieve good laryngeal anesthesia. One should wait for 2 or 3 minutes after irrigating with the lidocaine over the trachea and subglottic region before commencing the procedure. Topical anesthesia of the larynx may be performed, even if the patient is under general anesthesia, in order to prevent laryngospasm triggered by manipulation of the larynx. Further aliquots of lidocaine are administered over the nonanesthetized areas to be examined. Note that the lidocaine may be absorbed into the systemic circulation with possible toxic effects. Thus its use should be titrated to the recommended dose.

In the majority of cases the FB is inserted through the nose. The nasal insertion allows for a more stable and safe route because the bronchoscope may be bitten into by "the agitated child" if it is inserted through the mouth. The nasal route allows as well an easier approach and visualization of larynx and provides important information regarding the nasopharyngeal passages of the infant. Usually the 3.5 mm standard pediatric FB can be passed through the nasal passages, even in neonates.²⁰ The oral route should be reserved for very rare circumstances because tongue movement impedes the passage of the FB. We have the impression that the oral route is much less comfortable for the patient and the gag reflex is more easily stimulated when the bronchoscope is inserted by this route. In the few circumstances that the oral route is used, it is recommended to use a solid bite absorber.

Children with a tracheostomy may be examined through the tube if it is large enough or directly through the stoma. If one wishes to examine the position of the tube within the airway, the procedure may then be performed from above when the bronchoscopist may examine the tracheal cannula and the airway with or without the tracheal tube in place.

When visualizing the larynx, one carefully examines also the dynamics of the larynx especially if the clinical picture conforms to a laryngeal problem. The movement of the vocal cords and their baseline position are noted. The subglottic area sometimes will be difficult to examine on the

way in and should therefore be re-examined on the way out, too. When examining the lower airway, we recommend examination of the normal area first. One needs to constantly assess the clinical status of the patient, observe the monitors, and communicate with the patient appropriately. During the procedure, supplemental oxygen is administered to the patient through a nebulization mask in which there is a central hole through which we can insert the bronchoscope into the nasal passages. In this way, the patient may receive the required supplemental oxygen during the entire procedure (O_2 saturations are checked continuously with a pulse oximeter).

Of special interest to the anesthesiologist is the possibility of using the different types of FBs for intubation, since on occasion endotracheal intubation may be extremely difficult with conventional maneuvers. This is especially true in children with oropharyngeal and cervical spine abnormalities. The 3.5 mm bronchoscope may be used to insert a 4.5 endotracheal tube; the 2.7 mm FB and the ultra thin 2.2 mm, which are relatively smaller tubes. (Lubrication of the bronchoscope is required). We recommend passing the tip of the FB through the tube and inserting the tip of the FB through the nose, larynx, and trachea, and only then threading the endotracheal tube down through the larynx and into the trachea. Bronchoscopy also helps to identify the position of the tip of the tube and its required distance from the carina.

A common technique used in pediatric patients with FB is lavage. It may be used for diagnostic and treatment purposes. The lavage fluid for diagnostic purposes is examined for organisms (bacteria, fungi) and cytology. The cellularity and relative amount of each cell (polymorphonuclear cells, eosinophils, etc.) are documented. Special staining for fat is required in order to rule out aspiration syndromes. Stains for hemosiderin, *Pneumocystis carinii*, etc., may also be done. The therapeutic use of lavage is mainly in cleaning the airways and the opening of the bronchi blocked with thick secretions. The bronchoalveolar fluid may be examined for immunological and biochemical studies.¹³

Bronchoscopy should always precede bronchography. Generally, the flexible bronchoscope allows us to perform a localized bronchogram without compromising the normal parts of the lung.

CLINICAL APPLICATION OF THE PEDIATRIC FB

Investigation of airway and lung disorders includes lung function tests, radiological studies, computed tomographic scans, and ventilation-perfusion studies with radionuclide lung scanning. However, there are still a group of problems which cannot be solved solely by any of the above techniques, and direct visualization of the airway with a bronchoscope is necessary.

As a general rule, all the indications that apply for the adult may be applied to the pediatric patient, but there are major differences between them. In adults, one is generally looking for signs of malignancy, while in infants and children we are more concerned with congenital abnormalities, foreign bodies and other causes of airway obstruction.

Common indications for using the flexible and rigid bronchoscope are

summarized in Table 1. In the majority of the cases, the indications for bronchoscopy are for diagnostic purposes. The therapeutic use is limited to the treatment of obstructing lesions of the airways, which may be foreign bodies, mucus plugs, mucoid impactions, granulation tissue, and tumors. The bronchoscope is individualized to each case and treatment includes extraction, bronchoalveolar toilet, or laser treatments.^{1, 7} The major diagnostic findings during bronchoscopy of the upper airway when the primary symptom is stridor include laryngomalacia, subglottic stenosis, and vocal cord paralysis. When the primary symptom is persistent wheezes, tracheal or bronchial malacia, foreign bodies, and tracheal compression are most common. Other common findings with FB are inflammatory changes, granulation tissue, mucus plugs, and anatomic variants.²⁰ The major findings following rigid bronchoscopy for all ages are foreign body, laryngomalacia, tracheomalacia, and mucus plugs.⁹

The most common indication for bronchoscopy in the pediatric patient is stridor. Therefore, it is important to examine the patient when the symptoms are most prominent. In general, laryngeal and supralaryngeal abnormalities are the reason for stridor with no expiratory component. Nevertheless, in 14% of cases of stridor with a laryngeal or supralaryngeal abnormality there was additional pathology below the glottis.²⁰ Therefore, a *complete* bronchoscopy is recommended in every case. The only occasion in which a limited procedure should be considered consists of abnormalities that cause severe narrowing of the airway, such as subglottic stenosis, edema, etc.

Laryngomalacia is the most common laryngeal problem in infancy. It is usually a benign, self-limited disorder, but in some severe cases the infants require a tracheostomy for several months. The endoscopic findings can be a soft elongated and omega-shaped epiglottis and/or large arytenoids that prolapse into the glottis during inspiration (Fig. 2A, B) and/or short epiglottic folds with a relatively large epiglottis. The FB is the instrument of choice for investigating stridor because it allows examination of the upper airways with the head in a natural position. Furthermore, in several cases the reason for stridor is due to a nasopharyngeal abnormality, e.g., very large adenoids and/or collapse of the pharyngeal walls, which may be visualized by the nasal approach used with the FB.

Table 1. *Indications for the Use of the Flexible and Rigid Bronchoscope*

FLEXIBLE BRONCHOSCOPE	RIGID BRONCHOSCOPE
Stridor	Foreign body (present or suspected)
Sleep-associated airway obstruction	Hemoptysis
Persistent hoarseness	Biopsy
Unexplained persistent cough	Patients for whom FB is indicated but are:
Unexplained or persistent wheezing	a. Uncooperative and therefore FB is not possible.
Recurrent or persistent pneumonia	b. Neonates and young infants on mechanical ventilation in whom an FB cannot pass through the endotracheal tube without compromising oxygenation and ventilation.
Persistent atelectasis	
Suspected congenital anomalies	
Suspected airway compression	
Bronchial toilet for therapeutic or diagnostic purposes	
Evaluation of tracheostomy	

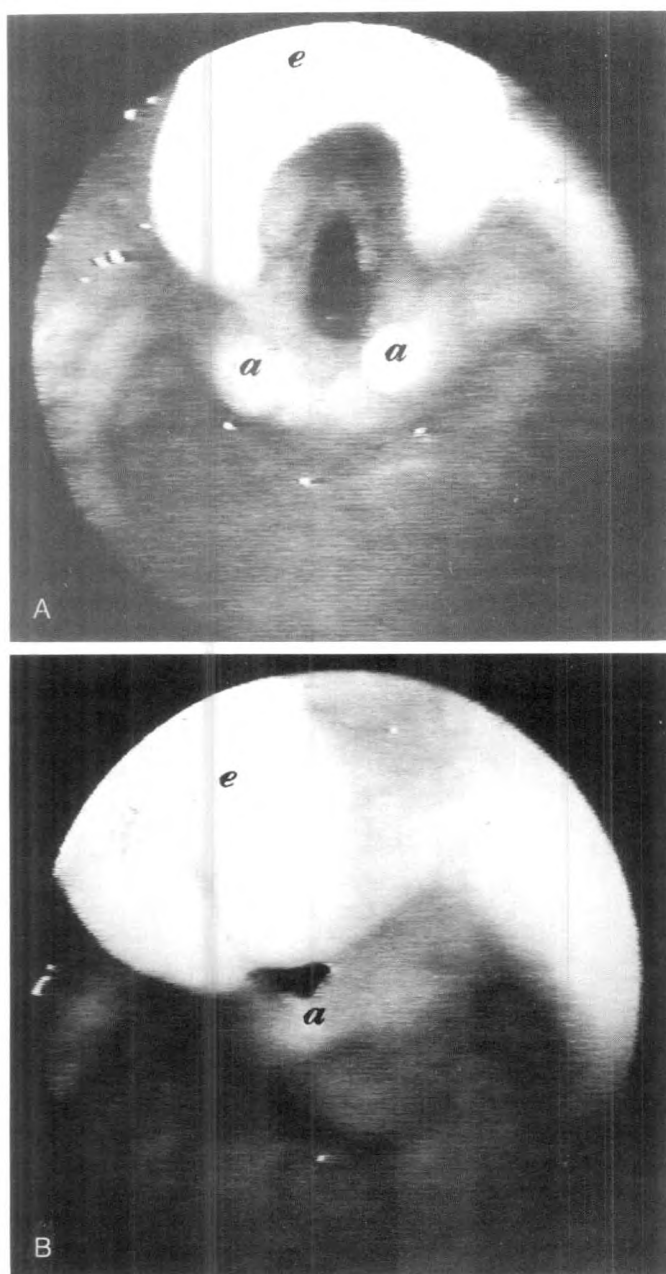


Figure 2. A, Normal larynx. Note epiglottis (*e*) and arytenoids (*a*). B, Soft, elongated and omega-shaped epiglottis (*e*) and large arytenoids (*a*) that prolapse into the glottis during inspiration (laryngomalacia).

The subglottic region should be examined carefully in a patient with stridor where no laryngeal cause is found to explain the "noisy breathing." Sometimes in an apparently normal subglottic region the 3.5 mm FB may pass with difficulty through the cricoid ring, impeding the small infant's ability to breathe adequately. The subglottic region can be stenotic due to a congenital malformation or to an acquired lesion (Fig. 3). The bronchoscopist can evaluate the degree of obstruction and recommend how aggressive the treatment should be. This information is essential as well for the anesthesiologist if the infant requires tracheal intubation for surgery. We emphasize the importance of a detailed examination of the vocal cords in each infant. The examination must include baseline position and when the patient is phonating or crying. The normal vocal cords abduct during inspiration and adduct during expiration. However, when paralysis is present, the vocal cords may abduct and adduct paradoxically, i.e., they close during inspiration and open during expiration. Hemangiomas in the airways are often associated with large hemangiomas on the body surface. When a child with suspected hemangioma is well sedated, the tumor may be less prominent and the epithelium covering the hemangioma may mask the vascularity of the tumor. The endoscopist should be familiar with the potential problem and look for loose and wrinkled mucosa. The child should be stimulated to cry or strain to "bring out" the hemangioma.

The normal trachea consists of cartilage rings which extend for about

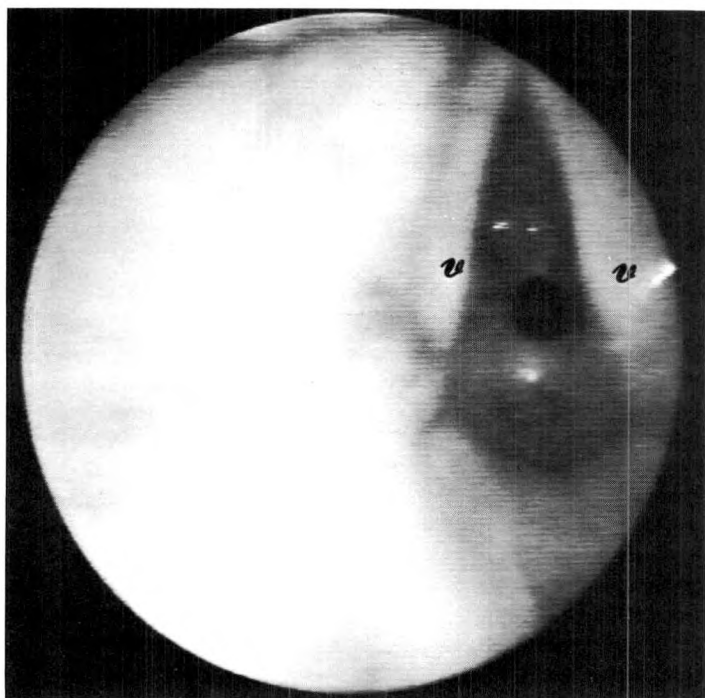


Figure 3. The subglottic region is stenotic due to a congenital malformation. Note vocal cords (v).

320 degrees. The posterior part of the trachea is membranous. In tracheomalacia, the tracheal walls collapse and the posterior and anterior wall may come into contact leading to severe airway obstruction (Fig. 4A, B). Tracheomalacia may be caused by an external compression of the airways. This is usually due to a vascular structure. It may be a vascular ring or enlargement of the heart or great vessels. Further studies are required to identify the precise cause.

Foreign body should always be suspected in a child with persistent or recurring pneumonia and/or atelectasis. We recommend that in all cases where a foreign body is suspected a rigid bronchoscopy be performed. In some cases in which the index of suspicion of a foreign body is not as high, we recommend performing the flexible bronchoscopy in the operating room, in the event a foreign body is found, to be able then to perform a rigid bronchoscopy under general anesthesia. When a child presents with hemoptysis we recommend rigid bronchoscopy. In cases in which massive bleeding occurs, it should be treated with topical epinephrine, tamponade of the bleeding site with pressure from a Fogarty catheter and blood transfusions.⁸ Bronchoscopy may assist in the investigation of pulmonary infiltrates (recurrent or persistent) through the procedure of bronchoalveolar lavage. The fluid should be examined for lipid-laden alveolar macrophage to rule out aspiration syndromes.¹¹

COMPLICATIONS

The frequency of complications during bronchoscopic procedures, flexible or rigid, is low. It depends, as in other fields of medicine, on the experience of the bronchoscopist and the team. The complications may be hypoxemia, hypercapnia with acidosis, arrhythmias, laryngospasm, bronchospasm, infection, pneumothorax, hemoptysis, direct trauma to the nasal tissue or larynx, and subglottic edema with stridor. The hypoxemia may be prevented by using the special mask described above and close monitoring of the patient. The hypercapnia is more difficult to monitor but if attention is given to air entry during the procedure and the procedure is performed rapidly we should prevent the hypercapnia and the acidosis.

Arrhythmias may be caused—by hypoxemia and/or vagal stimulation. They are prevented by adequate oxygenation and by adequate topical anesthesia of the larynx. Generally, this complication is not frequent. Thus we do not routinely administer atropine before or during a bronchoscopy. However, should bradycardia occur during the procedure, the bronchoscope should be withdrawn and adequate oxygenation ensured.

Concerning infections, one should note that pediatric flexible or rigid bronchoscopies cannot be done in a completely sterile environment. However, we rarely see iatrogenic infections from bronchoscopy. Attention should be given to adequate cleaning and sterilization between patients.

Pneumothorax is rare. One author²⁰ reports on two cases out of 1095 flexible bronchoscopies and only one of these required a chest tube. Direct trauma to the nasal passages and the larynx should be prevented, but occasionally epistaxis or hemoptysis occurs. Generally the bleeding will

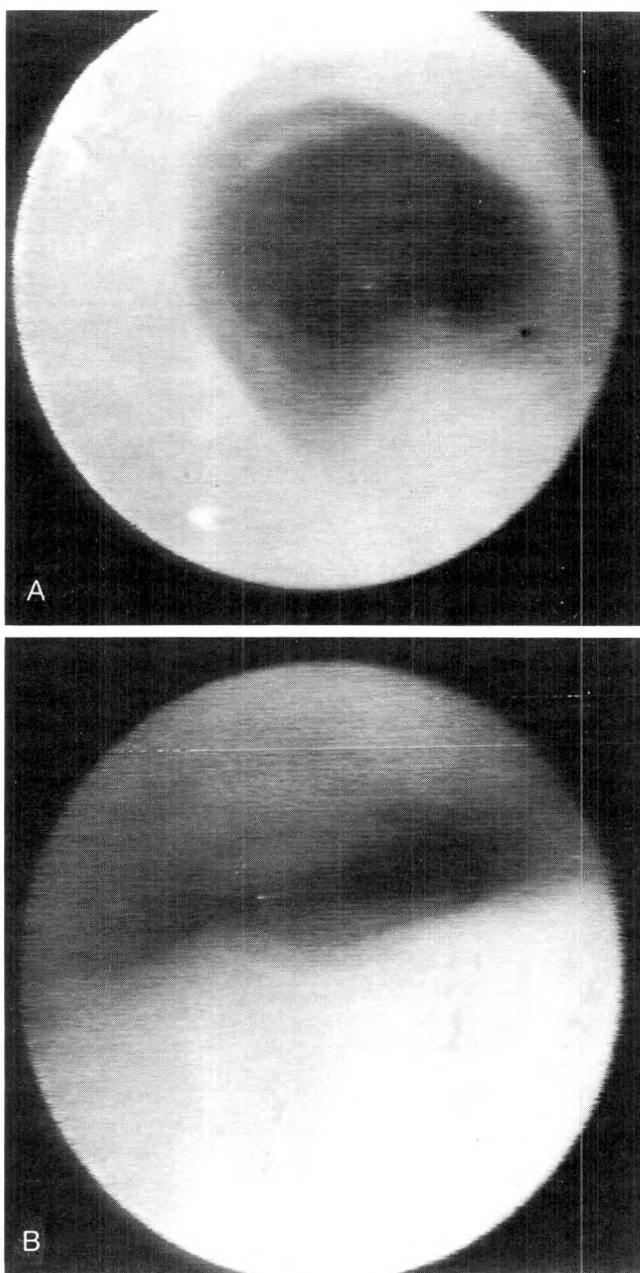


Figure 4. A, Normal trachea. B, Tracheomalacia. Note: the tracheal walls collapse and the posterior and anterior wall may come into contact, leading to severe airway obstruction.

stop spontaneously. On occasions, a mild stridor due to subglottic or laryngeal edema is heard. In most cases, it does not prolong the hospitalization of the child. Racemic epinephrine inhalations may be administered in more severe cases. A report comparing the complications between rigid and flexible bronchoscopies in adults has shown that the complication rate is lower with flexible bronchoscopies.¹¹ In a review of 364 rigid bronchoscopies in children, only three cases of bleeding were reported and these were very mild and transient. Stridor and hoarseness were described in less than 1%.⁸ Concerning contraindications for bronchoscopy, we did not withhold bronchoscopy in any case where we were convinced that the child needed the procedure. One should be very careful, however, in children with bleeding disorders and critically ill and hypoxemic children. In these cases, we recommend performing rigid bronchoscopy in the operating room under controlled conditions with the surgical and anesthesiology teams.

CONCLUSIONS

Bronchoscopies in the pediatric patient are no more a mystery or unbeatable challenge. They have become, undoubtedly, a relatively simple and safe procedure which is a valuable aid in the diagnosis and treatment of children with airway and respiratory problems. The choice of the rigid or flexible instrument should be based on the indications in each individual patient. Safety and success, as in all other fields of medicine, come once one is cautious, well trained, and well equipped.

ACKNOWLEDGMENTS

The authors wish to express their gratitude to Professor Simon Godfrey for permission to publish the illustrations used in this text.

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Address reprint requests to

I. David Todres, MD
Department of Anesthesiology
Massachusetts General Hospital
32 Fruit Street
Boston, MA 02114

Learning Fiberoptic Intubation

Andranik Ovassapian, MD and Sharon J. Yelich, MD†*

Fiberoptic airway endoscopy has introduced a new dimension in airway management because it has proven to be an excellent tool for both evaluation of the airway and for tracheal intubation under difficult circumstances. However, its use in the anesthesia community has spread slowly. A 1988 survey of academic department chairs, members of the Society for Education in Anesthesia, as well as private practice anesthesiologists, queried which procedural skills should be learned by anesthesia residents. Fiberoptic intubation received the highest priority.¹⁸ Results of 170 questionnaires completed in 1980 during a scientific exhibit of the American Society of Anesthesiologists and in 1981 at the International Anesthesia Research Society Annual Meeting showed that more than 75% of respondents have never used the fiberscope or have very limited experience with it.¹⁴ Analysis of 749 questionnaires completed during 21 fiberoptic workshops conducted by our department from 1984 to 1989 indicate that 90% of anesthesia departments have their own fiberscopes. However, 75% have either never used it or have used it a few times and have abandoned it because of very high failures rate (Tables 1, 2).

These surveys clearly indicate that lack of perceived necessity, cost, or availability of fiberscopes in the United States are not the factors in low utilization of the fiberscope by anesthesiologists. Rather, the need is perceived and the scopes are there, but they are not being used. The setting for many anesthesiologists' initial efforts to learn this new skill on their own is usually less than ideal. Frequently, the first attempts to use the fiberscope are in the setting of a difficult intubation; failure is the expected outcome. Lack of training and experience constitute the most common causes of failure of fiberoptic intubation and the cause of limited use of the fiberscope¹⁵ (Table 3).

Fiberoptic intubation is different from conventional intubation techniques and requires new psychomotor skills. We believe that the psychomotor skills of fiberoptic endoscopy are no more difficult to learn than rigid

*Director, Department of Anesthesiology, V.A. Lakeside Medical Center, Chicago, Illinois.

†Assistant Professor, Clinical Anesthesia, Northwestern University Medical School, Chicago, Illinois.

Table 1. Fiberoptic Workshop Surveys: Use of the Fiberscope*

	YES	NO	NOT ANSWERED
1. Do you have fiberscope in anesthesia department?	677 (90.4%)	72 (9.6%)	0
2. Have you used fiberscope for tracheal intubation?	502 (67.0%)	246 (32.8%)	1 (0.1%)
3. Is fiberoptic intubation being taught at your department?	78 (10.4%)	641 (85.6%)	30 (4.0%)

*Continuing Medical Education Workshops conducted by faculty of Northwestern University Medical School and Veterans Administration Lakeside Medical Center Department of Anesthesia between 1984 and 1989.

Of 918 participants, 749 (81.6%) completed the questionnaires.

Table 2. Fiberoptic Workshop Surveys: Number of Fiberoptic Intubations Performed

None	246 (32.8%)
1-5	315 (42.1%)
6-10	96 (12.8%)
11-25	48 (6.4%)
>25	35 (4.7%)
Not answered	9 (1.2%)

Continuing Medical Education Workshops conducted by faculty of Northwestern University Medical School and Veterans Administration Lakeside Medical Center Department of Anesthesia between 1984 and 1989.

Of 918 participants, 749 (81.6%) completed the questionnaires.

Table 3. Causes of Failure of Fiberoptic Intubation

Lack of training and experience
Presence of secretions and blood
Inadequate topical anesthesia
Decreased space between the tip of the epiglottis and the posterior pharyngeal wall
Distorted airway anatomy
Inability to advance the endotracheal tube over the scope into the trachea
Inability to withdraw the fiberscope from the endotracheal tube

(From Ovassapian A: Tracheal Fiberoptic Intubation. In Ovassapian A (ed): Fiberoptic Airway Endoscopy in Anesthesia and Critical Care. New York: Raven Press, 1990, p. 74, with permission.)

Table 4. Cognitive Skills for Fiberoptic Intubation

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1. Indications for fiberoptic intubation
 2. Limitations of fiberoptic intubation
 3. Airway anatomy
 4. Ability to recognize abnormal airway anatomy
 5. Appropriate premedication for airway endoscopy
 6. Intravenous sedation for an awake intubation
 7. Pharmacology and application of local anesthetic agents
 8. Appropriate monitoring of the patient
 9. Causes of fiberoptic failure
 10. Alternate means to gain control of the airway
-

laryngoscopy and spinal or epidural techniques. Introducing a new psychomotor skill into a clinical practice requires a different approach than introducing new cognitive concepts, such as proper use of a new drug.

There are many important aspects in teaching and learning the psychomotor skill of fiberoptic intubation. Tables 4 and 5 show the cognitive and technical skills needed for successful fiberoptic airway endoscopy and intubation. "Hands on" work is necessary to educate the hands to maneuver the fiberscope and the eyes to recognize and interpret the view, especially in pathologic states.²⁰ Manipulation of the instrument should be natural and spontaneous and can easily be achieved by working on a tracheobronchial model. While one may tend to think only of necessity of technical expertise with the instrument, the cognitive skills listed here and discussed elsewhere in this issue are very important and can be learned through study and discussion.^{2, 11, 19} Violation of cognitive principles can cause unsatisfactory outcome, even when the operator has good technical skills with the instrument.

Successful teaching of a new psychomotor skill requires a teacher who is knowledgeable and proficient in the skill and displays a positive attitude toward the clinical applications and effectiveness of the new technique. In the case of fiberoptic intubation, often attempts for intubation or teaching fiberoptic intubation have been conducted by an instructor without previous experience or skill. In addition, the learner must be given the opportunity to practice the skill until it is mastered under adequate supervision with constructive evaluation and feedback from the instructor.

Models are particularly useful in teaching psychomotor skills. In our speciality, models have been used to teach such skills as rigid laryngoscopy and intubation, cardiopulmonary resuscitation, spinal and epidural technique, and brachial plexus block.¹⁻⁹ Recognizing that the available evidence strongly supports the use of models and simulators in teaching psychomotor skills,^{4, 7} we developed a graduated training program using models and

Table 5. Technical Skills Needed for Fiberoptic Intubation

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1. Maintenance of a functional fiberscope
 2. Ability in checking fiberscope and ancillary equipment for proper functioning
 3. Dexterity in instrument manipulation
 4. Different approaches to tracheal intubation
 5. Completion of intubation within an acceptable period of time
-

patients to assist clinicians in learning fiberoptic technique, building confidence, and introducing it in their practices.¹⁶ Our current training program, modified from the original, is outlined below; it is based on current educational principles for teaching and learning a psychomotor skill with well-defined learning objectives.^{4, 7, 12}

A METHOD FOR TEACHING AND LEARNING FIBEROPTIC INTUBATION

Our method for teaching fiberoptic intubation is conducted in seven steps (Table 6).

Demonstration of the Fiberscope

The physical characteristics of the fiberscope, the manner in which it functions, and how it should be handled are discussed first. The care of the instrument and how to avoid damaging it are emphasized. In-service training for all physicians, nurses, and technicians who use and clean the fiberscope is essential and should be conducted as early as possible to avoid unnecessary breakage so that a functional fiberscope is always available in the service. Instrument breakage contributes to underutilization of these instruments for two reasons: First, the department is often left without a functional fiberscope, and second, restrictive administrative policies to protect the fiberscope in some institutions can result in unavailability of the instrument for routine use by the members of the department. Our experience is that a fiberoptic bronchoscope used properly and carefully should give more than 5 years of service when used on a daily basis.

Practice on Tracheobronchial Model

In the next stage, the learner, after observing a demonstration by the instructor, practices on the tracheobronchial model to learn how to manipulate the fiberscope and become familiar with the characteristics of its visual field (Fig. 1). The learner should have access to the instrument and the model for unlimited practice. The student should practice until he can quickly and predictably maneuver the instrument in a given direction to expose various segments of the lung model. An acceptable level of dexterity of manipulating the fiberscope is achieved with 3 to 4 hours of independent practice. This step is critical for learning effective and proper manipulation of the fiberscope, and efforts should be made to go through this step before the fiberscope is used on patients. During this exercise, referring to a

Table 6. *Steps in Teaching Fiberoptic Tracheal Intubation*

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- | |
|--|
| 1. Demonstration of the fiberscope |
| 2. Practice on tracheobronchial model |
| 3. Practice on intubation mannequin |
| 4. Awake fiberoptic tracheal intubation |
| 5. Fiberoptic intubation under general anesthesia |
| 6. Practice positioning endobronchial tube in tracheobronchial model |
| 7. Use of fiberscope for separation of two lungs |
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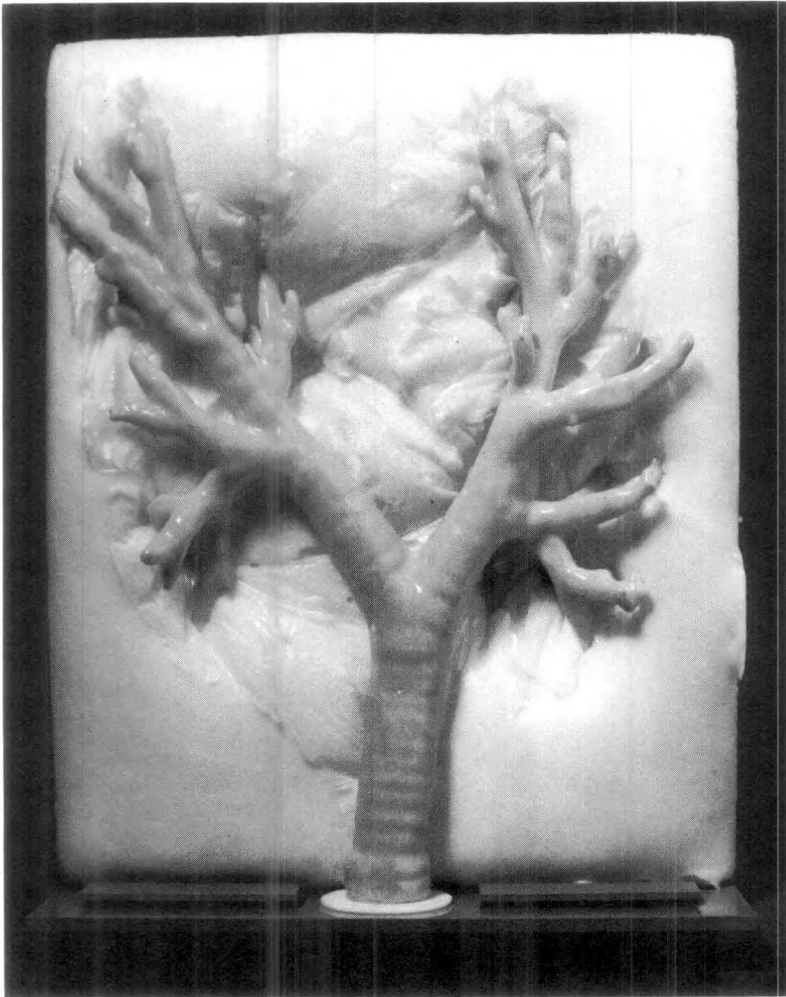


Figure 1. Tracheobronchial model.

diagram of tracheobronchial anatomy helps the learner to memorize various divisions of the bronchial tree and their relation to the mainstem bronchi.

Practice on Intubation Mannequin

After the instructor outlines the technique, he uses an intubation mannequin to demonstrate the steps of fiberoptic intubation, both oral and nasal, in both conscious and anesthetized patients (Fig. 2). The fiberoptic technique for checking endotracheal tube position by measuring the distance between the tip of the endotracheal tube and carina is also demonstrated. The learner practices each procedure several times until he knows the progression of steps; he is then ready to perform fiberoptic intubation on patients. Practicing intubation technique on a mannequin is important but is less critical than practicing on the tracheobronchial model.

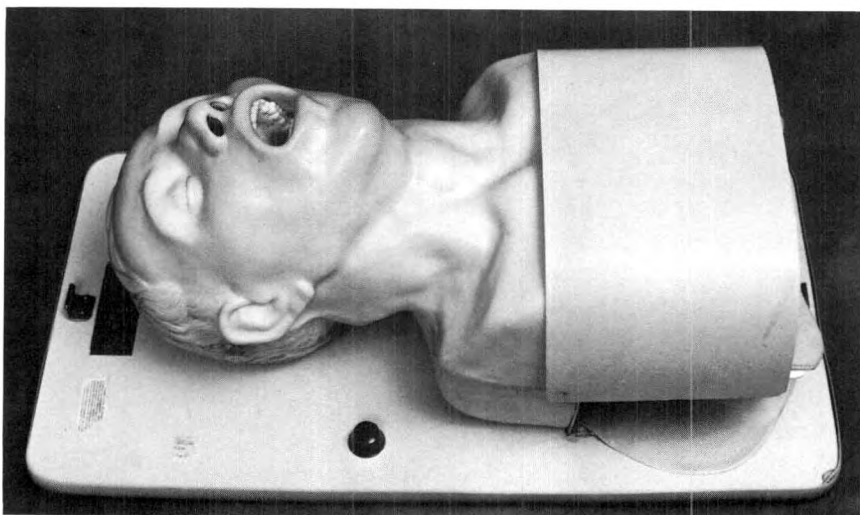


Figure 2. Laerdal adult intubation model.

Practice on Awake, Sedated Patients

A sedated patient with good topical anesthesia provides ample time and good opportunity under stable operating conditions for the inexperienced to learn the use of the fiberoptic. Principles of safe titration of sedation, patient monitoring, and various methods of anesthetizing the airway are all very important aspects of a successful awake intubation. These factors must be emphasized and taught, as well as indications and techniques of fiberoptic intubation. The live patient presents the learner with new challenges, such as secretions, blood, fogging, inadequate topical anesthesia with airway reactivity, and movement. The learner who now knows how to manipulate the fiberoptic confidently can concentrate his efforts on dealing with these problems, any one of which could cause or contribute to a failed intubation. Because patients accept awake, sedated, fiberoptic intubations well, more liberal use of awake fiberoptic intubation should be encouraged in the learning process. There is no doubt that the awake intubation plays a major role in management of patients with anticipated difficult intubation or difficult ventilation. The anesthesiologist must be adept at all aspects of awake intubation, not just manipulation of the fiberoptic, which can also be learned during routine intubations under general anesthesia. The ability to identify the epiglottis and vocal cords and recognize and solve problems created by secretions and laryngeal movement may also be learned by exposing the larynx in patients in the recovery room who are recovering from general anesthesia who consented to airway inspection by the fiberoptic through a nasal airway placed during general anesthesia.

Practice on Patients under General Anesthesia

After gaining some experience with awake intubations, the learner should use the fiberoptic for tracheal intubation of patients under general

anesthesia. Initially, patients with normal upper airway anatomy scheduled for routine surgical procedures are intubated with the fiberscope instead of a rigid laryngoscope. The instructor demonstrates how intubation is performed under general anesthesia and explains the assistant's role. These routine intubations under general anesthesia can be done easily with the fiberscope with apnea time of 30 to 60 seconds. After 10 awake fiberoptic intubations, most residents have been successful in over 90% of their first few intubation attempts under general anesthesia. As learners become more experienced in the use of the fiberscope, they will be able to use it with increasing success for intubating patients with abnormal airway anatomy and patients in whom rigid laryngoscopy under general anesthesia has failed.

Practice Positioning Endobronchial Tubes in the Tracheobronchial Model

A tracheobronchial model is used for practice of placement and verification of position of both right- and left-sided double-lumen endobronchial tubes. It is extremely beneficial that the learner understand not only the correct placement but also the various ways that these tubes may be misplaced or malfunction and how this can be identified and corrected.

Practice Separating the Lungs

After the learner has practiced the technique of double-lumen tube placement in the model, he can use the fiberscope when separating the lungs is necessary. With a limited number of intrathoracic operations being performed, it is crucial that each case be used effectively for teaching fiberoptic techniques. With the use of the fiberscope, placement of the right-sided endobronchial tube becomes practical and reliable. Unless an anatomic variation or pathologic change prevents the use of the bronchial tube, a right-sided tube is used for all left thoracotomies and a left-sided tube is used for right thoracotomies.

OTHER APPROACHES TO TEACHING FIBEROPTIC INTUBATION

Mostafa¹³ has modified the graduated training program described by Dykes and Ovassapian⁶ such that after exercise in models and exposing the larynx in patients recovering from general anesthesia, orotracheal intubation is practiced in patients undergoing general anesthesia. Nasotracheal intubation is reserved until the learner has practiced the oral approach. Intubation of conscious patients is permitted when 30 anesthetized patients have been successfully intubated. Others also describe training in fiberoptic tracheal intubation during the course of routine general anesthesia.^{3, 10} Regularly performed nasal intubation in patients undergoing oral surgery was done using the fiberscope.³ Patients were under general anesthesia, breathing spontaneously, with nose and larynx topically anesthetized. No data were provided about the time used for intubation, the success or failure rate of the learner, or the speed of learning.³

Using an anesthetized pig as a clinical model for teaching fiberoptic

intubation has been suggested.⁸ The initial experiences have been positive; however, preparation of an animal model has many shortcomings including cost, time, management, and justification of using an animal for learning a technical skill.

ADDITIONAL LEARNING AIDS

In addition to the tracheobronchial model and intubation mannequin, other equipment is helpful in teaching fiberoptic intubation. The fiberoptic teaching attachment makes it possible for the instructor and learner to observe simultaneously, and thus the instructor can provide step-by-step demonstration of the intubation procedure.¹⁵ A disadvantage is that it reduces the light by half so that the image is darker. Video cameras and television screens can be used to demonstrate the techniques for tracheal intubation, airway evaluation, or the positioning of endobronchial tubes. These devices are frequently available in the operating room because orthopedics, urology, and other services use them for performing operations, for teaching, and for documentation. Various intubating airways are available, and although not essential, they can be helpful in the intubation process. A face mask with endoscopy port is available; this allows continued mask ventilation by an associate during the intubation process.

PROFICIENCY

When an anesthesiologist is considered proficient in the use of the fiberscope is difficult to say. In our research on fiberoptic intubation, a randomized clinical trial of 32 learners clearly showed that those who learned from the graduated program were more successful than those who learned from a traditional "see one, do one" approach.¹⁷ Another of our studies suggests that learners who have mastered the use and proper manipulation of the fiberscope by practicing on a tracheobronchial model and have used the fiberscope to expose laryngeal structures in patients recovering from general anesthesia can be successful in over 85% of their first six attempts at nasotracheal intubation in patients with normal airway anatomy.¹⁶

Johnson and Roberts reported that an acceptable level of technical expertise in fiberoptic intubation can be obtained by performing 10 intubations in anesthetized patients.¹⁰ This is based on the performance of four anesthesia residents with at least 8 months of training and no previous experience in fiberoptic intubation. Each resident had a 15-minute practice session on a teaching mannequin with an instructor observing before attempting orotracheal intubation in anesthetized patients. The time for intubation was measured from the last breath by mask to the first breath through endotracheal tube minus the time during which repeat mask ventilation was performed. A learning curve was established by plotting the mean time for intubation against 15 consecutive fiberoptic intubations by each resident (Fig. 3). In the first five intubations, the success rate for

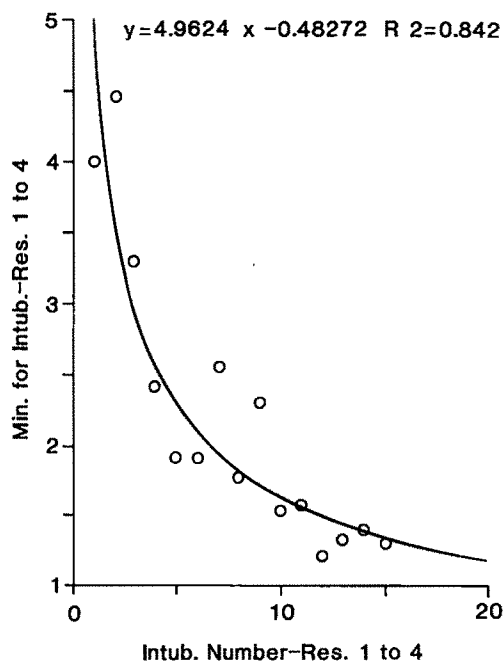


Figure 3. Group learning curve for four residents. The curve represents mean time (minutes) for intubations (x axis) versus number of intubations (y axis) performed by four residents. (From Johnson C, Roberts JT: *J Clin Anesth* 1:344-349, 1989; with permission.)

first attempt at fiberoptic intubation was 50%, which was improved to 90% in patients 6 to 10 and 100% in patients 11 to 15. They conclude that an acceptable level of technical expertise in fiberoptic intubation is achieved within 10 intubations and the time of intubation remains flat after the 10th intubation at the average level of 1.2–1.5 minutes. Their findings were similar to the experience of Delaney and Hessler who reported their clinical experiences in the use of the fiberscope for nasotracheal intubation in emergency room; they found significant decrease in time of intubation after their 9th to 10th intubations.⁵

The level of proficiency is difficult to measure under clinical conditions. In our experience most learners, after practicing on tracheobronchial and intubation models, learn to use fiberscopes effectively in awake patients with normal airway anatomy after 15 to 20 such intubations. The same number of intubations under general anesthesia seems to be adequate to give the learner the necessary skill and experience for independent use of the fiberscope. The amount of training or experience necessary for safe and effective use of the fiberscope in patients with compromised airways, however, is not known and needs to be studied. Based on observations of a few of our anesthesia fellows and staff who have used the fiberscope for longer periods of time, 100 or more uses for airway evaluation, tracheal intubation, and endotracheal tube change, and double-lumen tube placement may be needed to gain the necessary experience for independent and successful use in patients with compromised airway.

Achieving competence in any technical skill depends on several factors: number of times the technique has been used, variation in speed of learning and manual dexterity among learners, and the level of supervision and expertise of the instructor. Overall performance of learners should be

considered when privileges are given to work independently, not just the number of times that particular skill has been used. The American College of Physicians has set minimum criteria necessary to obtain clinical competence in flexible sigmoidoscopy, esophagogastrosopy, and colonoscopy.^{2, 11, 19} Minimal competency standards for cognitive and technical skills to perform fiberoptic tracheal intubation, placement and positioning of double-lumen tubes, and limited bronchoscopy should be established. The minimum number of fiberoptic intubations should be only one criterion. Each learner should be evaluated individually for overall performance.

If teaching of fiberoptic laryngoscopy is initiated in early part of anesthesia training, there will be ample time and opportunity for every learner to become proficient in the use of the fiberscope. In addition to tracheal intubation, use of the fiberscope for evaluation of the airway, for positioning of double-lumen tube, or for limited bronchoscopy will help speed up the development of the technical dexterity that is needed for smooth and successful use of these instruments.

The fiberscope is not an experimental instrument and has its well-defined place for airway management as a state-of-the-art technique. In the operating room, all awake oral and nasal intubations are potential uses for the instrument. It can be used in the recovery room and intensive care unit whenever there is a need to visualize the vocal cords after thyroidec-tomy, after bilateral neck dissections, to evaluate upper airway obstruction, for differential diagnosis of postextubation stridor, to inspect for damages caused by prolonged intubation, and to evaluate the airway prior to tracheostomy closure.

INTRODUCING THE FIBERSCOPE INTO ANESTHESIA PRACTICE

The independent practitioner with no experience with fiberoptic intubation faces special challenges when learning and introducing a new technical skill into his practice. Participating in fiberoptic workshops with demonstrations and practice on tracheobronchial and intubation models is very helpful for the beginner. A well-designed workshop with adequate time for practical sessions should be the first step for introducing this technique into one's practice.⁶ A cart with all necessary equipment should be made ready so that it can be summoned upon request. A system should be established so that routine care and cleaning of the instrument is arranged. The fiberscope is a relatively expensive piece of equipment. The initial investment for purchasing one fiberscope, one light source, and one bronchoscopy cart will cost between \$10,000 and \$15,000, depending on the type and quality of instrument selected. It is critical that a technician be assigned for handling the fiberscope and maintaining the fiberoptic cart in working condition. The final step in successful incorporation is to use the fiberscope for routine tracheal intubation in patients with normal anatomy and easy airway. To do this, one should keep the attending surgeon and the operating room nurse aware of the situation and purpose of fiberoptic intubation. If time is a major factor, the selection of patients with

peripheral operation is recommended, because the surgeon can start the patient preparation while the anesthesiologist is performing fiberoptic intubation. The first few attempts may be used for such things as exposing the larynx and clearing secretions. Very soon, laryngeal exposure time will be minimized and time will be available to continue the process of intubation. Another physician, a nurse, or a technician must provide the necessary help for performing intubation under general anesthesia. Patients accept awake fiberoptic intubation well, so any patient with anatomic features suggesting the possibility of difficult intubation should be considered for awake intubation. Very soon, the practitioner will feel comfortable and will use the fiberscope in any patient who may benefit from it. Many clinicians, after participating in a fiberoptic workshop, have done so successfully.⁶

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Some Applications of Fiberoptics in Anesthesia

George D. Shorten, FFARCS(I), FCAnaes,
and James T. Roberts, MD†*

In 1987, Murphy¹¹ described how endoscopic visualization of the upper airway might facilitate endotracheal intubation. For more than 2 decades, fiberoptic techniques have found new applications in the fields of pulmonary medicine, pediatrics, otolaryngology, thoracic surgery, trauma, intensive care, and anesthesiology. As recently as 1984, Hogan et al⁷ wrote that "the fiberoptic laryngoscope tantalizes anesthetists by promising a rational method of visualizing the hard to find larynx but failing to be helpful in a high proportion of attempts." A decade of technical advances, a growing range of ancillary devices, and a formalized approach to the dissemination of psychomotor skills and knowledge have won fiberoptics an undisputed place in clinical anesthesiology. In 1989, Vaughan¹⁹ could categorically state that "it is of paramount importance that anesthetists learn to use a fiberoptic bronchoscope competently."

It is probably true that technical advances determine what is achievable using flexible fiberoptic techniques. Certainly, the expertise and confidence of an individual practitioner determine the clinical uses to which such techniques are put. Thus, the fiberscope has recently been used in two related areas of interest to the practicing anesthetist namely airway management in the emergency department and endotracheal intubation of the patient with a full stomach.

In 1975, Mulder et al¹⁰ described three groups of patients in whom the fiberoptic bronchoscope facilitated endotracheal intubation. These were patients with soft tissue contractures of the mouth and neck, those with combined mandibular/facial fractures, and those with unstable fractures or fracture/dislocations of the cervical spine. These latter two groups represent a common problem for those involved in emergency medicine.

Examination of the published experience of Schafermeyer,¹⁶ Delaney

*Instructor in Anesthesia, Harvard Medical School; Clinical/Research Fellow, Department of Anesthesia, Massachusetts General Hospital, Boston, Massachusetts

†Professor of Anesthesia, Massachusetts General Hospital, Boston, Massachusetts

and Hessler⁶ and Mlinek et al⁹ reveals a number of recurrent and important points. In the series described by Delaney and Hessler, indications changed as the study progressed. Initially, the selected patients were those who were stable following overdoses and who required intubation for airway protection during gastric lavage (29 patients, or 52% of the study group). Later, indications broadened to include respiratory failure (14%), status epilepticus (9%), cerebrovascular accident or coma (7%), head trauma with possible cervical injury (9%) and partial upper airway obstruction (9%). Patients with significant hypoventilation or apnea, massive facial injuries, or complete airway obstruction were considered inappropriate for this technique. The 35 patients described by Mlinek et al⁹ comprised those with respiratory failure (49%), following overdose (17%), cardiac arrest (11%), trauma (11%), intracranial bleeding (9%) and seizures (3%). Of the 31 patients with "medical" indications, six had an anatomic condition (kyphosis, clenched teeth or trismus), which influenced their selection. In ten others, a fiberoptic technique was only attempted after blind nasotracheal intubation had failed. The trauma group comprised two patients with gunshot wounds to the neck, one with clenched teeth and one with a flail chest. As a result of their experience, Mlinek et al concluded that those patients who need fiberoptic intubation represent only a small minority of those requiring emergency airway management. These authors list as specific indications known anatomic abnormalities, suspected or confirmed cervical spine injury, penetrating neck injuries and failed nasotracheal intubation. Delaney and Hessler considered that a fiberoptic technique offers specific advantages in patients in respiratory distress who may be intubated in the sitting position.

Operator experience is an important determinant of success or failure and of the time required to intubate using this technique. Most of the attempts in the Delaney study were made by one of two attending physicians who had no previous experience with fiberoptic intubation. After each had completed ten, the time required to intubate fell dramatically. Intubations in the Mlinek series were performed by either a staff physician or a chief resident who had achieved familiarity with the technique by practicing on a mannequin. "Medical" patients were successfully intubated in 1.8 ± 1.4 minutes and trauma patients in 3.0 ± 2.2 minutes. It is worth noting that attempts that eventually failed took much longer (7.8 ± 3.3 minutes). One may conclude that, if in skilled hands intubation is not quickly achieved, the attempt is unlikely to succeed and should be abandoned.

Schafermeyer¹⁶ attributed a high failure rate (24%) with fiberoptic techniques in 16 emergency intubations to excessive secretions, bleeding or operator inexperience. Specific difficulties encountered in Delaney's series included inability to pass the fiberscope through either naris, secretions, bleeding caused by a previous blind nasal attempt, patient agitation and inadequate lubrication of the fiberscope. The six failures in Mlinek's series all occurred in the "medical" group. The reasons given were diminished view due to secretions, blood or vomitus.

Two important questions, relevant to all the emergency intubations described, remain unanswered. Does the fiberscope have a role in the

intubation of a patient with a potentially "full stomach" and if so, to what extent may the upper airway be safely topicalized? Recently, Ovassapian et al¹² have comprehensively examined this problem. These authors described oral or nasal fiberoptic intubations in 129 patients considered to be at high risk for aspiration. It was concluded that this technique provides a valuable alternative to standard rapid sequence induction or awake intubation using a rigid laryngoscope in such patients. In only one patient, who vomited a large quantity of blood, was it necessary to resort to rigid laryngoscopy. No patient regurgitated during the procedure or developed evidence of aspiration. Advantages of the technique include the usefulness of the fiberscope if a difficult intubation is unexpectedly encountered and the lesser cardiovascular response.¹³ It is certainly less painful than direct laryngoscopy in an awake patient but the patient will not always be amnesic for the procedure.

Recommendations regarding topicalization in these circumstances vary greatly. The problem is that inadequate anesthesia increases the likelihood of failed laryngoscopy or laryngospasm. However, complete topicalization of the upper airway diminishes protective reflexes, thus increasing the risk of aspiration, should vomiting or regurgitation occur. Local anesthesia of the tongue, vallecula, and lingual surface of the epiglottis preserves the laryngeal closure reflex but is associated with a high failure rate at attempted direct laryngoscopy.⁸ Walts²⁰ considers that these areas alone may be safely anesthetized in those at risk of aspiration. Thomas¹⁸ suggests that while laryngeal spraying with local anesthetic and superior laryngeal nerve block are permissible, transtracheal injection should be avoided. On 29 occasions in Ovassapian's series, 3 ml of lignocaine 4% was injected through the cricothyroid membrane without ill effects. This technique aims to preserve lower respiratory tract reflexes so that if material is inhaled, it will be forcibly expelled by coughing. This approach has been described as "revolutionary"¹⁹ but requires further evaluation before it may be relied upon in such a perilous area as the prevention of aspiration.

A number of attempts have been made to combine fiberoptic and direct laryngoscopic devices.

Figure 1 illustrates a laryngoscope¹⁴ designed in 1981 by one of the authors (Roberts) to facilitate blade adjustment, the monitoring of trainees and video recording of laryngoscopic appearances. This Adjustment, Monitoring, and Recording (AMR) laryngoscope may be adapted to accept a variety of flexible fiberscopes and offers a number of advantages over standard direct laryngoscopy. The laryngoscopic line of vision is normally determined by the upper incisor proximally, and the glottis distally. Moving the proximal determinant to a point a few centimetres behind the tip of the blade improves the view of the glottis in potentially difficult intubations. A supervising anesthetist may easily confirm correct placement of the endotracheal tube while teaching intubation. A permanent record of the laryngeal appearance and the process of intubation may be obtained by attaching a video camera to the eyepiece.

The AMR laryngoscope incorporates two additional design features. A handle that pivots to either side will facilitate blade placement in the presence of a prominent sternum or an assistant's hand applying cricoid

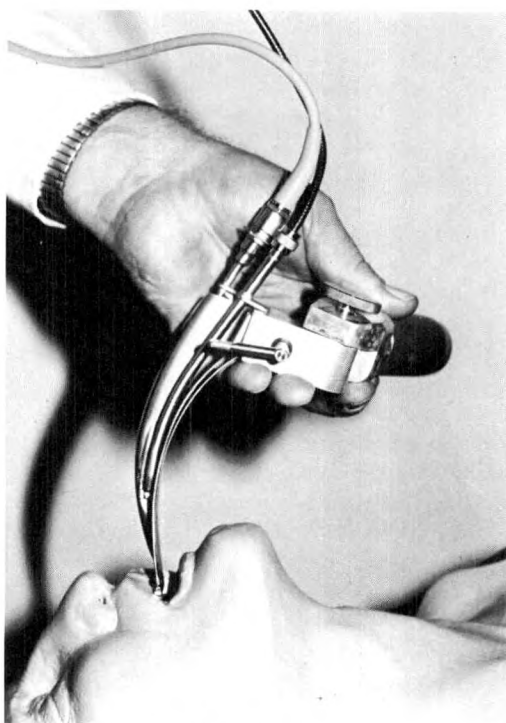


Figure 1. The Roberts laryngoscope.

Table 1. *Advantages and Disadvantages*

Advantages

- Rapid visualization of the vocal cords
- Rapid oral tracheal intubation
- Low risk of "failed intubation"
- Less trauma to lips and teeth
- Easier to master than fiberoptic laryngoscope
- No neck extension or flexion required

Disadvantages

- Difficult to introduce in the awake patient
 - Intubating forceps require right-handed laryngoscopy
-

pressure. By locking the handle in the "left" position, a valuable teaching point may be illustrated. Placing the handle in this position eliminates the tendency to lever the blade on the patient's upper incisors. By rotating a control lever, the blade may be lengthened (from the size of a Macintosh no. 3 to Macintosh no. 4 blade) without withdrawing the laryngoscope.

Scott¹⁷ in 1983 modified the blade of a Macintosh laryngoscope for fiberoptic illumination and suggested that this might be particularly useful for a preintubation inspection of the larynx by the surgeon in patients with laryngeal cancer.

The Bullard laryngoscope, (designed by Dr. Roger Bullard, former Director of Obstetrical Anesthesia at the Medical College of Georgia), represents another successful attempt to combine the advantages of direct and fiberoptic laryngoscopy. The rigid anatomically shaped blade is correctly positioned by inserting it into the oral cavity and over the dorsum of the tongue as the handle is rotated from the horizontal to the vertical position. The blade tip may be placed in the vallecula or posterior to the epiglottis. Upward (vertical) pressure reveals a view of the glottis. Either a styletted endotracheal tube (ETT) (with the curve conforming to that of the Bullard blade) or an ETT with a directable tip may be visualized as it is advanced past the tip of the blade and between the vocal cords. Alternatively, with the operator holding the handle in his right hand, an intubating forceps, which grips the ETT through the "Murphy eye," may be used. Suction may be applied or oxygen delivered through a working channel that opens just proximal to the distal end of the blade. In their assessment of the adult version, Saunders and Geiseck¹⁵ list the advantages and disadvantages they encountered (Table 1). It is also noted that the direction of insertion and of pull required to expose the larynx are slightly different from those used for classical direct laryngoscopy. Using the pediatric version, Borland and Casselbrandt⁵ found that, in 90 of 93 attempts, that laryngoscopy was easy and fast. Excessive secretions made visualization impossible in two patients and the authors conclude that "appropriate use and timing of an antisialogogue and oral/nasal suctioning are important components of the technique." Oxygen desaturation in a third patient was believed to be partly accountable to the absence of an oxygenation channel (a feature that is now present in both production models).

Bronchoscopy and laryngoscopy are not the only techniques facilitated by fiberoptics that are of interest to the anesthetist. Blomberg¹⁻⁴ has described his experience using epiduroscopy over the past 6 years, initially on autopsy cases and more recently in patients undergoing partial laminectomy. The technique used entails identifying the epidural space using an 18G Tuohy needle and loss of resistance to air. Having noted the depth of the space, an Olympus Selfscope (model SES 2211S—external diameter, 2.2 mm) is introduced with the aid of a trocar and sheath into the adjacent cephalad lumbar interspace. The endoscope, equipped with a wide angle lens directed at 90 degrees to the longitudinal axis may be rotated to view the epidural space in both cranial and caudal directions. Visibility is easily improved by injecting 2 to 3 ml of air to open up the space in the autopsy cases, although such improvement was less in patients.

The most significant feature observed (in all 48 autopsy cases) was a

distinct dorsal connection in the midline between the dura mater and the flaval ligaments in the form of strands of connective tissue. In two cases, these strands constituted a complete membrane in the dorsomedial plane. As a result of this observation, Blomberg undertook a further autopsy study comparing midline with paramedian approaches for lumbar epidural puncture. He concluded that, by using the paramedian approach, the risk for accidental dural puncture is less, and that the catheter is more likely to pass in a straight cephalad direction.

The extent of the view of the epidural space obtained in patients was very limited. This is probably due to the presence of normal circulation and normal cerebrospinal fluid pressure and confirms that in living subjects only a potential space exists. The use of epiduroscopy to extract an accidentally cut epidural catheter is therefore likely to be technically difficult.

As anesthetists' familiarity with fiberoptic techniques grows, new applications and new pitfalls are identified. As smaller (ultrathin) fiberscopes have become available, their use in neonatal and premature airway management has become a reality. Both this, and the use of the fiberscope to facilitate placement and localization of single- and double-lumen endotracheal tubes are described elsewhere in this issue. In this article, we have briefly described some of the clinical uses to which fiberoptic techniques have recently been put. We have also described some of the newer fiberoptic devices available. It is likely that the long and growing list of anesthetic applications of fiberoptics is far from complete.

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Address reprint requests to

Dr. George Shorten, FFARCS
Department of Anesthesia
Massachusetts General Hospital
32 Fruit Street
Boston, MA 02114

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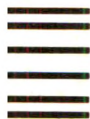
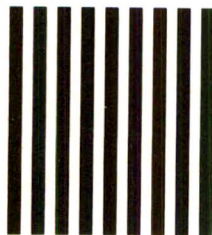
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